

NASA Hydrologic Applications

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Program Manager, Water Resources*

*Microwave Land Hydrology Workshop
Oxnard, California*

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22 Oct. 2008



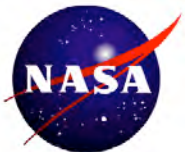
Goulburn-Murray Water

<http://wmp.gsfc.nasa.gov>

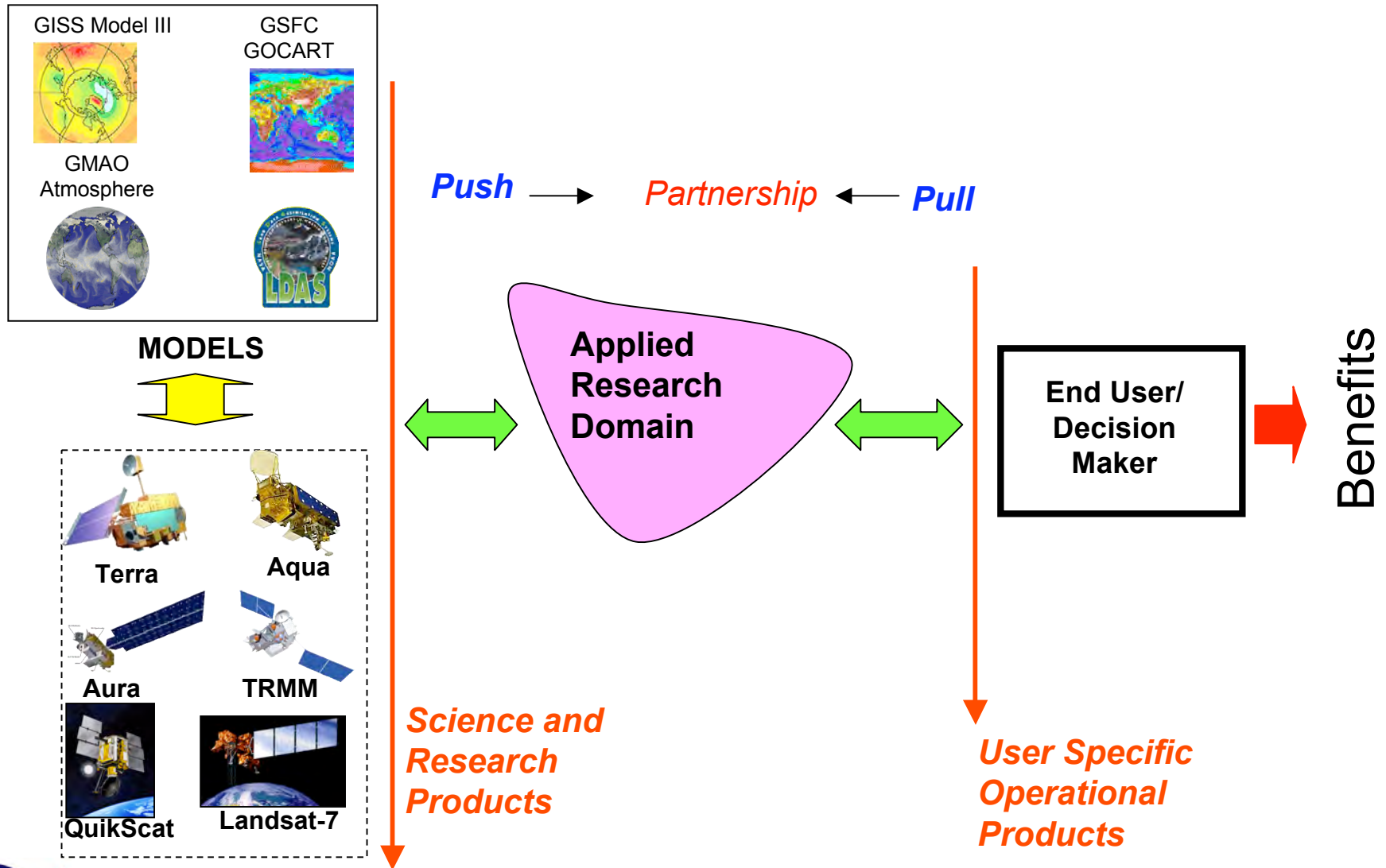


OUTLINE

- NASA Applied Sciences Program
- NASA Land Information System Modeling and Data Assimilation Test Bed
- Selected Hydrologic Applications



Research to Application



Remote Sensing Missions

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NASA Societal Benefit Areas



**Natural
Disasters**



**Water
Resources**



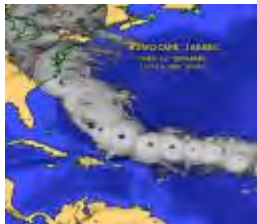
Ecosystems



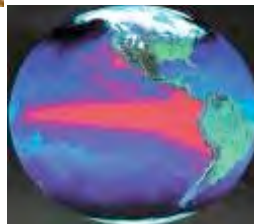
Agriculture



**Air
Quality**



Weather



Climate



Public Health

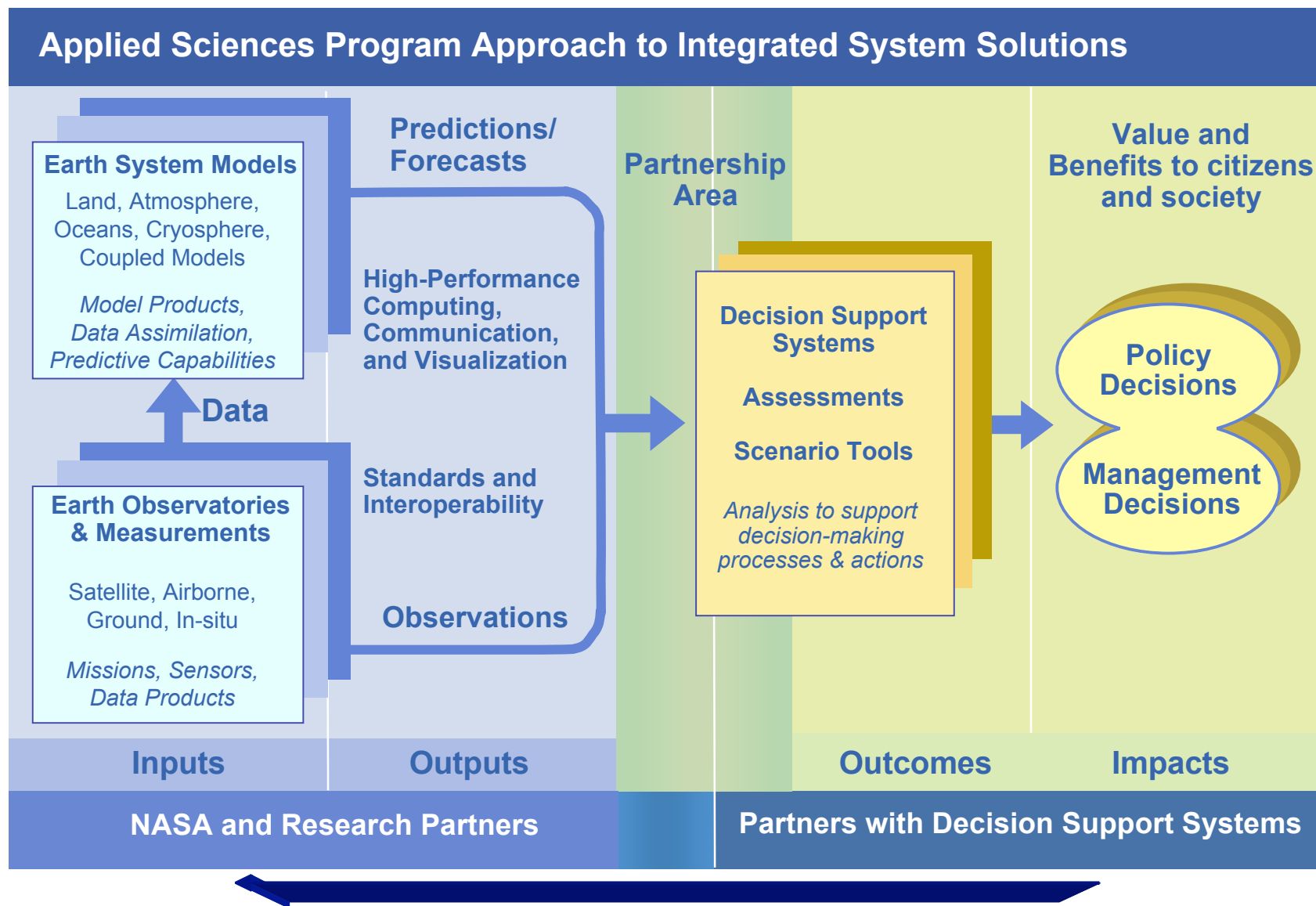


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NASA Applied Sciences Program

Integrated Solutions & Decision Support

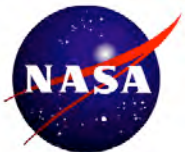


NASA Applied Sciences Program

Water Resources

Vision: *NASA Earth science routinely used in an integrated water resources approach both for the U.S. and internationally for the sustainable use of water and the reduction and mitigation of extreme events of floods and drought. Also towards contributing for the next generation Decadal Survey satellite missions.*

- Primarily through other US federal agencies (NOAA, USDA, EPA, etc.) and national water organizations (ASCE, AWRA) for broad application
- For many NASA satellite and modeling products (e.g., precipitation and streamflow) the application to data poor countries of the world may be much more valuable. Work through groups such as {GEO – Global Earth Observing, USAID, World Bank, DoS (Paul Simon Act Water for the Poor)} to work internationally.
- Recent Emphasis on Climate Impacts to Water Resources for Adaptations and Mitigation Strategies
- Recent ‘strong support’ of NASA Decadal Missions



NASA Earth Sciences and Applied Sciences Program (Decisions '08 Solicitation)

- **Integrated System Solution Projects - to 4-years** To discover and demonstrate innovative applications of NASA Earth science research and technology and to maximize the benefits to society of the nation's investments in the NASA Earth science research program. Strong end user and Decision Support Tool Focus. 145 proposals submitted. Select 20 to 23 Projects in early 2009, to 4-years @ \$230-\$310K/Yr}
- **Feasibility Studies – 12-18 Months.** Includes use of NASA products from upcoming, planned decadal missions to perform improvements to decision-making activities. (Select 9-15 projects in early 2009 from ~95 proposals; 12-18 months @ \$60-110K/Yr.



Water Resources Program Functional Themes –Projects Summary

<http://wmp.gsfc.nasa.gov>

FLOODS & STREAMFLOW FORECASTING

- **Improved streamflow** for NOAA River Forecast Centers.
- Using NASA satellite and modeling products for **Seasonal Forecast** in W. US
- NASA-NOAA-USGS **Flash Flood Project** using NASA products and modeling.
- Using NASA **Snow Products and LIS** for NOAA Snow and Water Forecast

IRRIGATION & WATER DELIVERY

Three projects are currently addressing various aspects of improving **ET estimates** for use in the BoR AWARDS-ET Toolbox and similar DSTs. Focus on using MODIS data and LDAS/LIS estimates of ET & soil moisture. One Iraqi irrigated agriculture mapping

DROUGHT

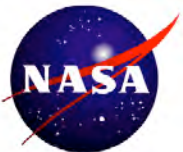
Four Projects. Two using satellite (AMSR-E, Quikscat/Sea Winds, MODIS and GRACE) and modeling/data assimilation products to improve the **US Drought Monitor**. Two other improving seasonal predictions and the downscaling of climate predictions for **US Drought Outlook**. In support of the National Integrated Drought Information System (NIDIS).

WATER QUALITY

Nonpoint source pollution project to assess the impact of MODIS land data products and impact of LIS precipitation and ET products to improve the continuous hydrologic model, HSPF, used in the EPA BASINS DST.

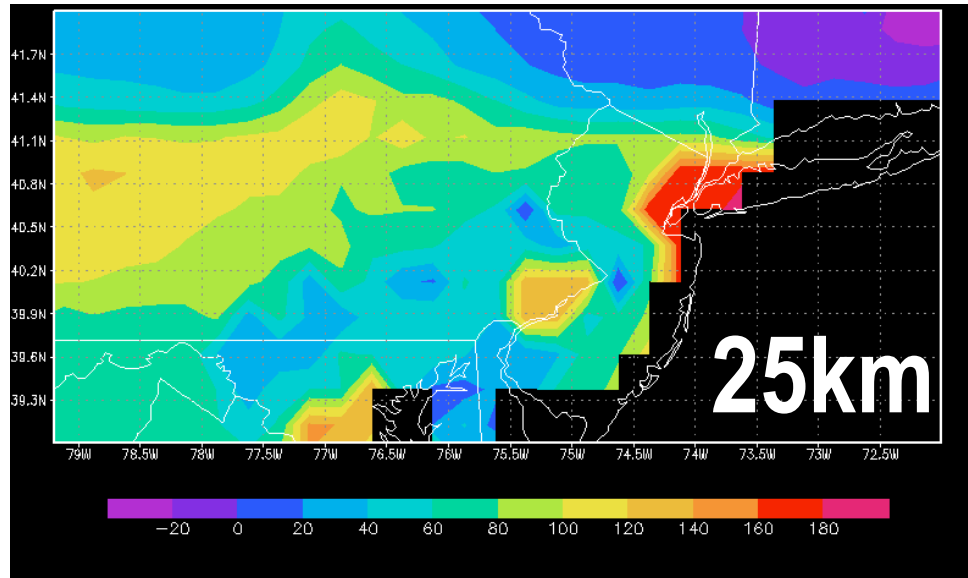
Modeling Data Assimilation System & Integration Using Remotely Sensed Data *NASA Land Information System (LIS)*

- NASA LIS Test Bed Used Operationally at NOAA NCEP and Air Force Weather Agency. Plans for NOHRSC, FEWS NET, Arab Water Council, Army and others.
- LIS: Global Land Hydrology Outputs to 1km and Finer
- Multi-model land Modeling Toolbox (Noah, CLM, Catchment, Sacramento, SiB, Snow-17, etc.) Flexible and modular for add-ons.
- Data Integration (in situ, ancillary, remote sensing)
- Data Assimilation Toolbox (NASA GMAO DA techniques for snow, soil moisture, & surface temperature)
- Earth System Modeling Framework for interoperability
- Available for down load (<http://lis.gsfc.nasa.gov>)

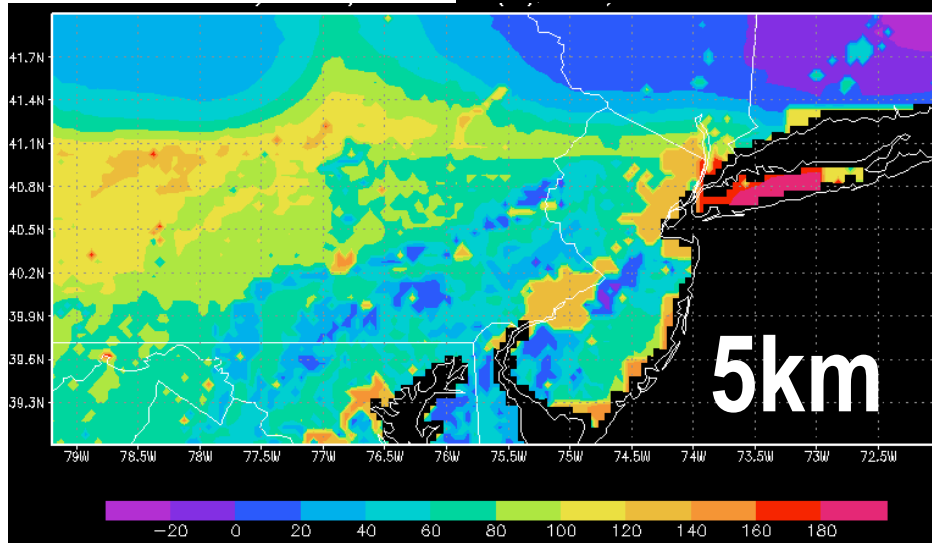


Scale & Hydrologic Applications

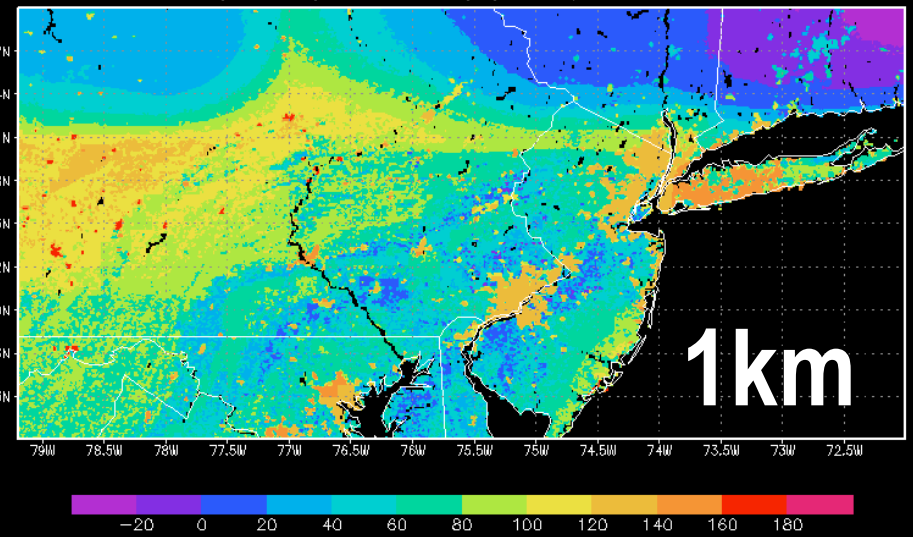
Global Scale



Meso Scale



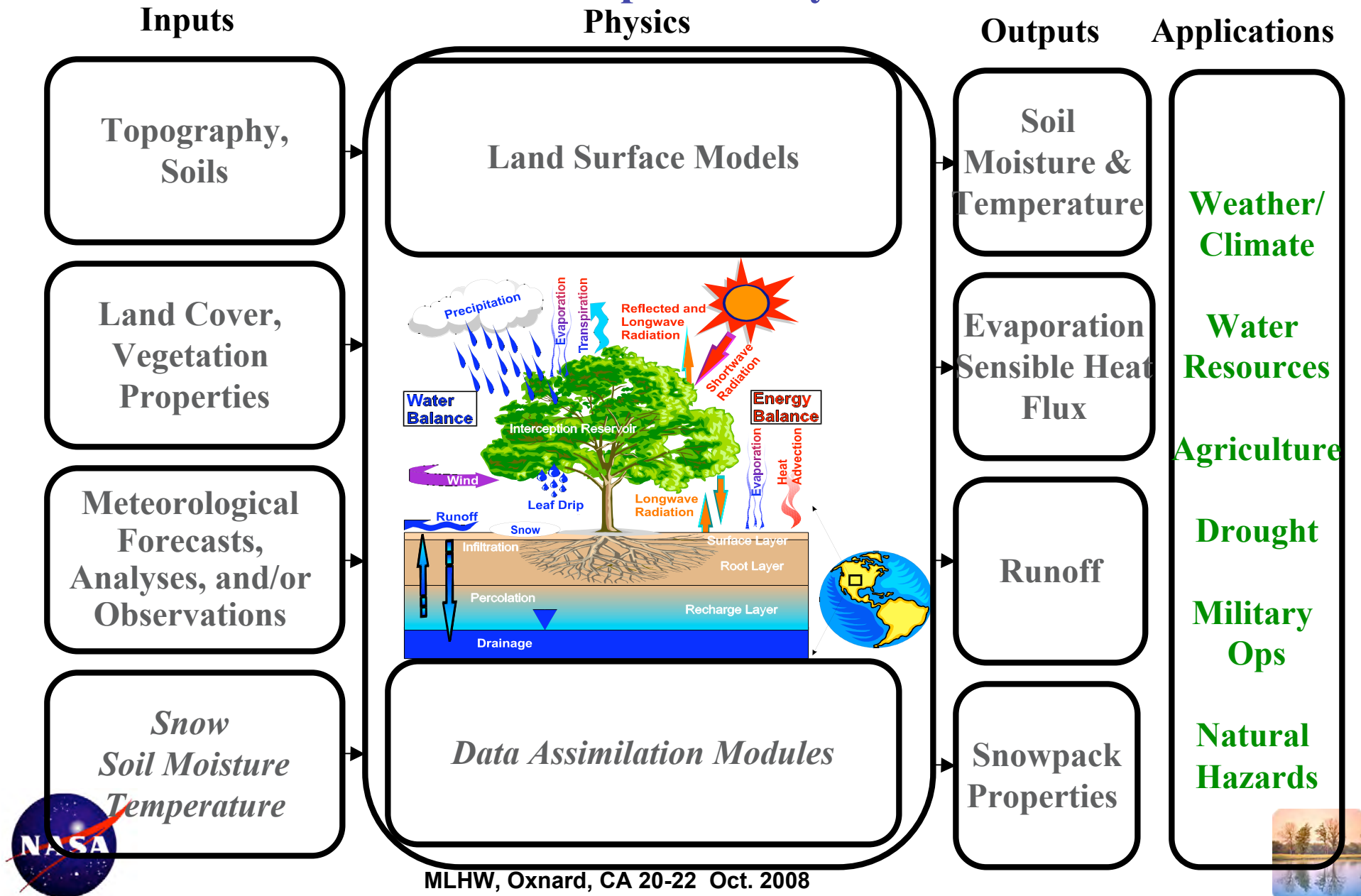
Fine Scale



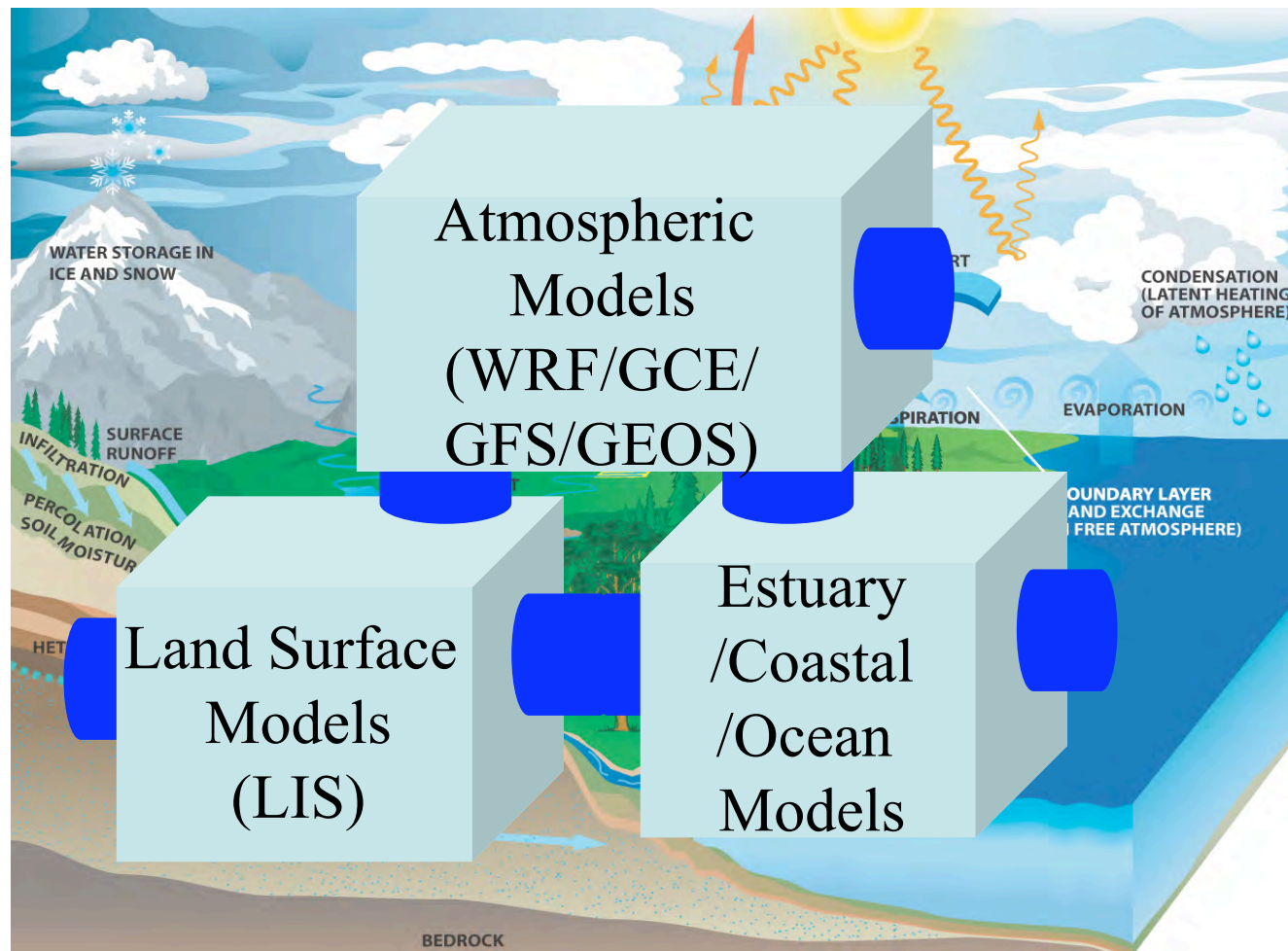
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NASA Land Information System Integration & Assimilation

Uncoupled/Analysis Mode



LIS Vision: Land Component for Earth System Models



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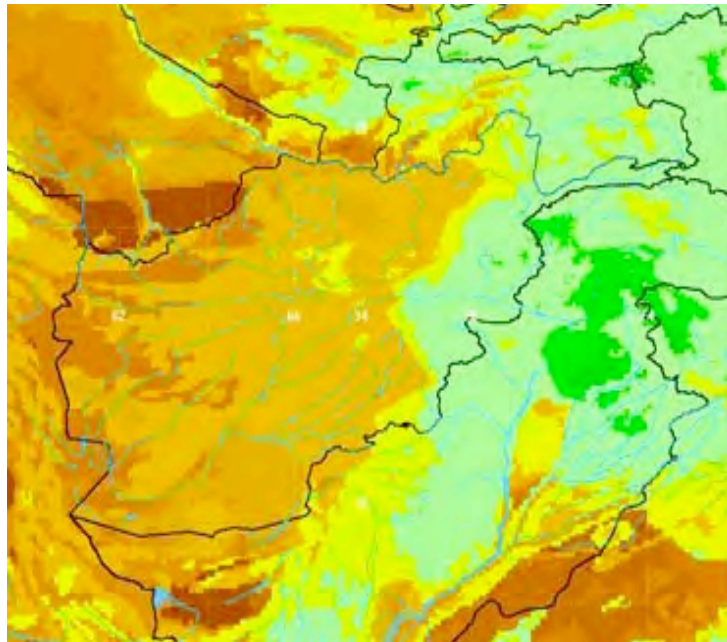


AFWA-NASA Land Information System (LIS)

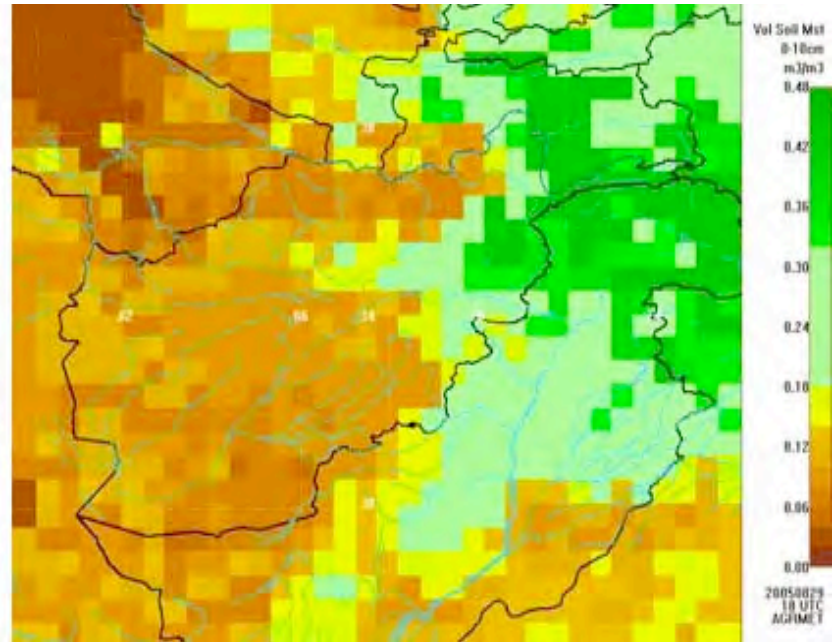
Air Force Weather Agency (AFWA) – Leveraged Project

- LIS Replaces AFWA's AGRMET (Agriculture-Meteorology), Global Soil Moisture and Temperature System

{Army Remote Moisture System (ARMS); Moran and others}



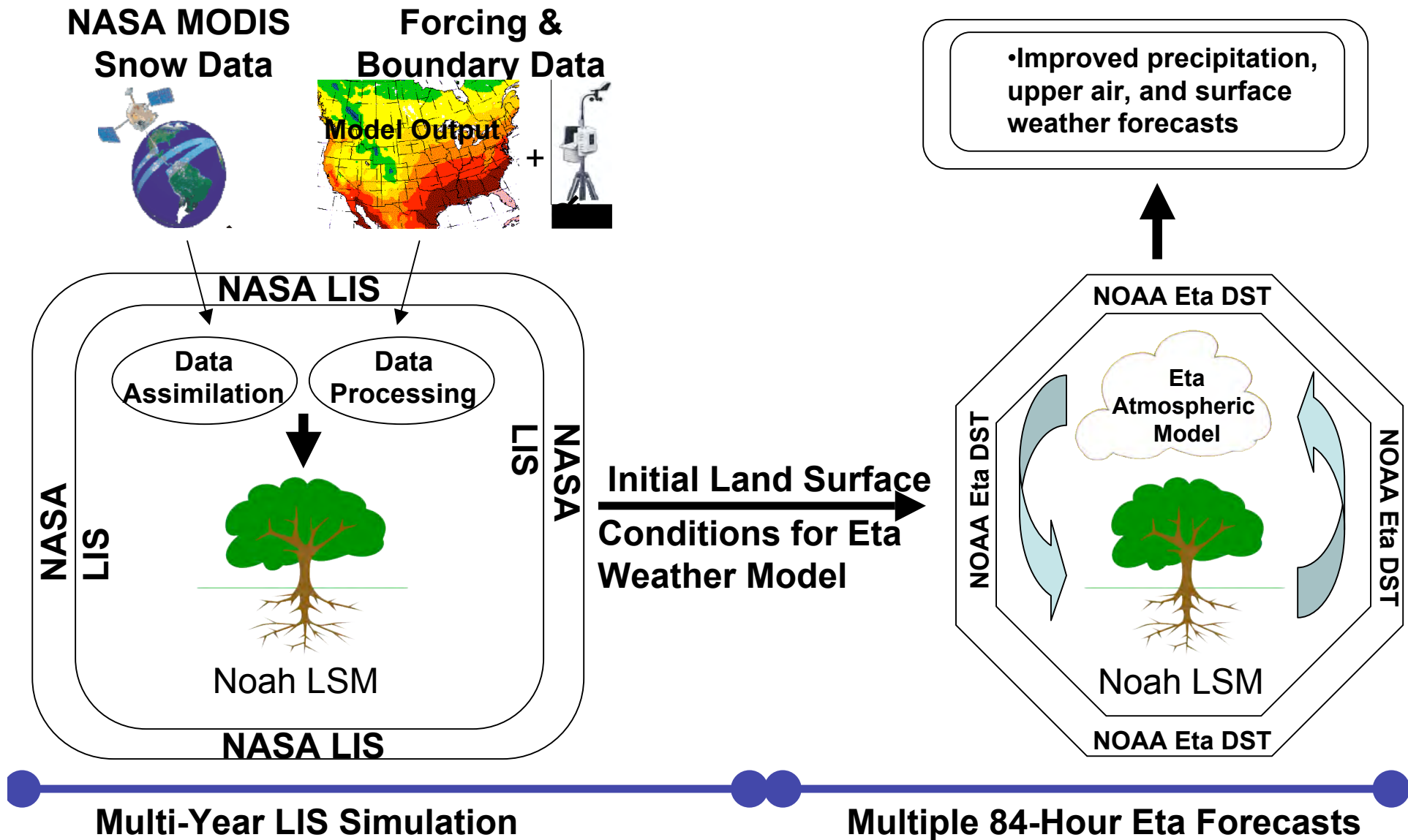
LIS Soil Moisture (1 km)



AGRMET Soil Moisture

29-August-2005 at 1800 UTC Covering Afghanistan and Portions of Pakistan

NASA-NOAA/NCEP Improved Weather Forecasting Using NASA Satellite Products & Land Information System (LIS)



Currently Used by NOAA NCEP in Global Forecast & Climate Forecast Systems

“Benchmarking NASA Snow Research Results in NWS Hydrological Decision Support”



Figure 1: Integrated Systems Solutions diagram showing model and observing system input DST outcomes and impacts for the NOAA National Snow Analysis (SNODAS) DSS.



Houser & Cline NASA Applied Sciences Program

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LIS Data Assimilation Example

- NASA/GMAO-developed capabilities for sequential data assimilation have been implemented in the NASA Land Information System (LIS) framework.
- LIS is a comprehensive system that integrates the use of various land surface models, assimilation algorithms, observational sources for users at NASA, AFWA, NOAA, USDA and other agency investigators.
- Capabilities have been demonstrated for assimilating soil moisture, snow and skin temperature observations.

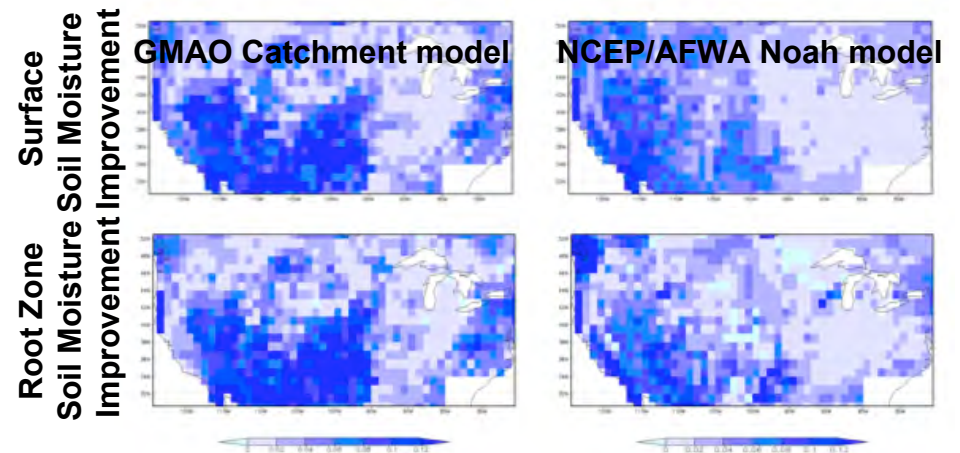


Figure 1: Soil Moisture Assimilation

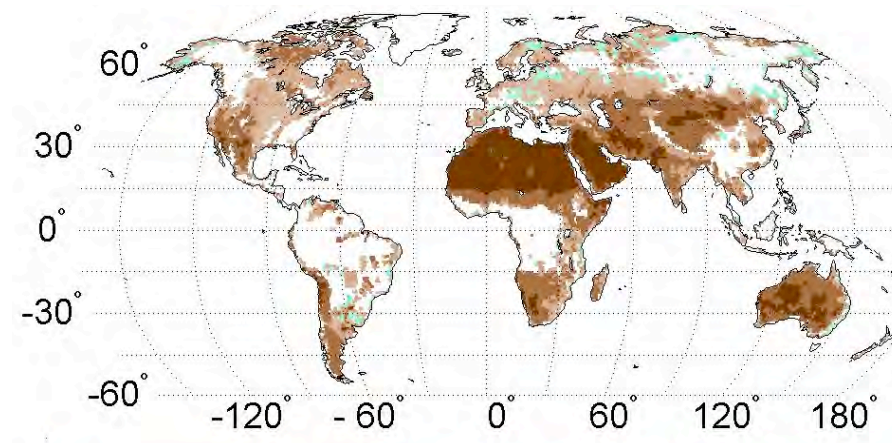


Figure 2: AMSR-E in to Catchment LSM

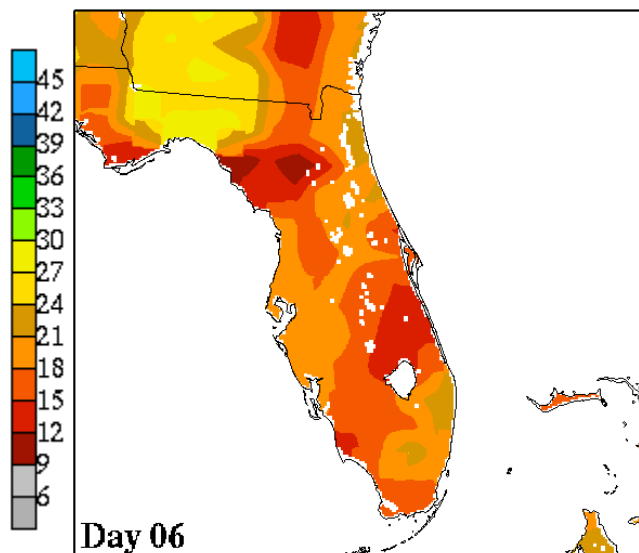


LIS-WRF Coupled Example

0-10 cm initial soil moisture (%)

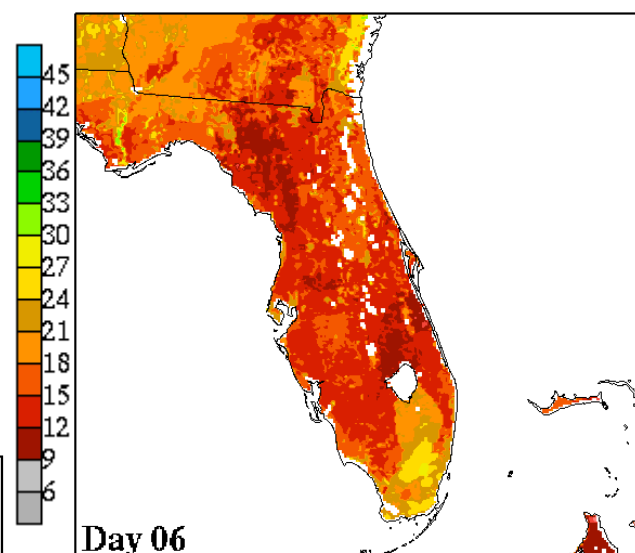
(1200 UTC 6 May 2004)

Eta soil moisture



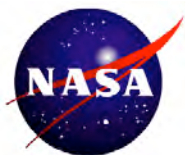
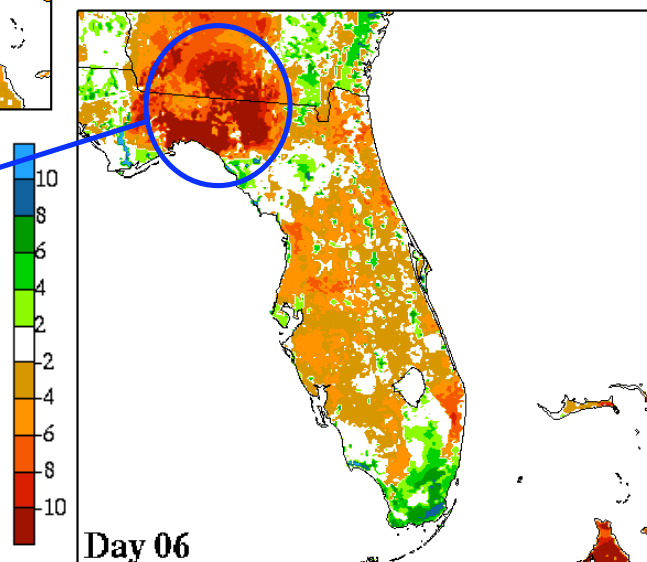
- Much more detail in LIS (as expected)
- LIS drier, especially over N. FL & S. GA
- LIS slightly more moist over Everglades

LIS soil moisture



Difference (LIS – Eta)

LIS Substantially Drier

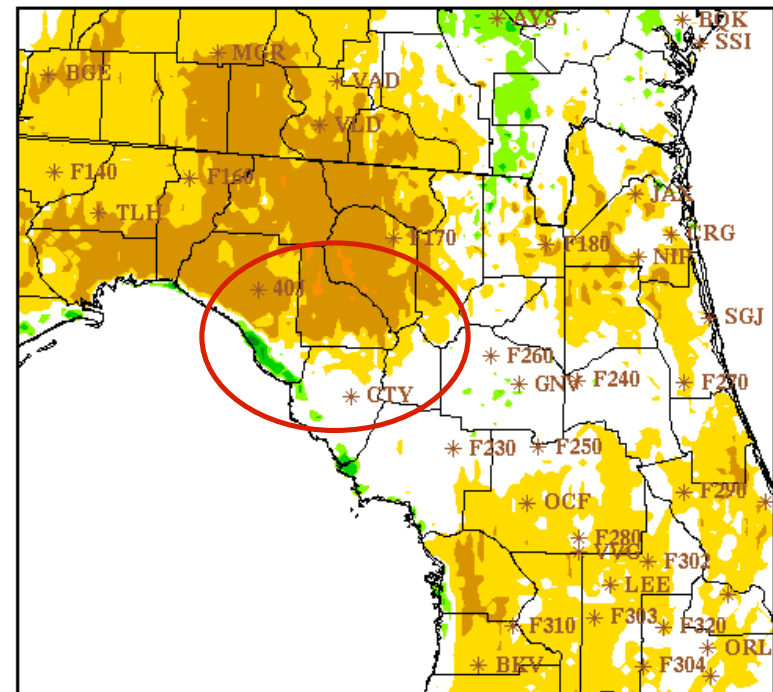
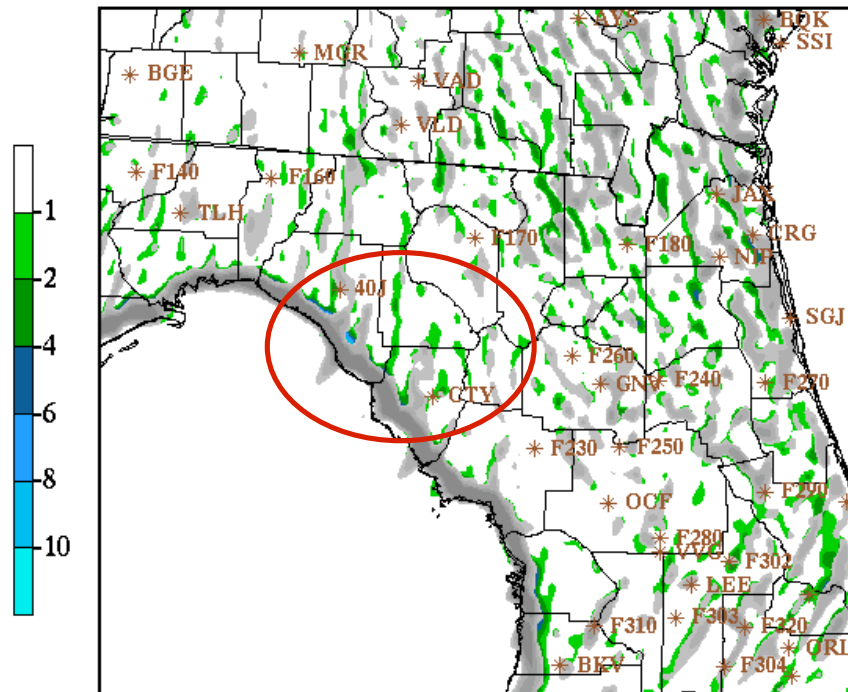


LIS-WRF Coupled Example

Sea Breeze Evolution Difference (1800 UTC 6 May to 0300 UTC 7 May)

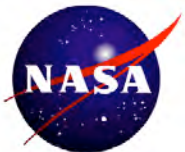
Divergence ($\times 10^{**4} \text{ s}^{**-1}$) valid 040506/1800V006

2-m Temp Diff (LISWRF - WRF) valid 040506/1800V006



(color=LISWRF ; gray=WRF)

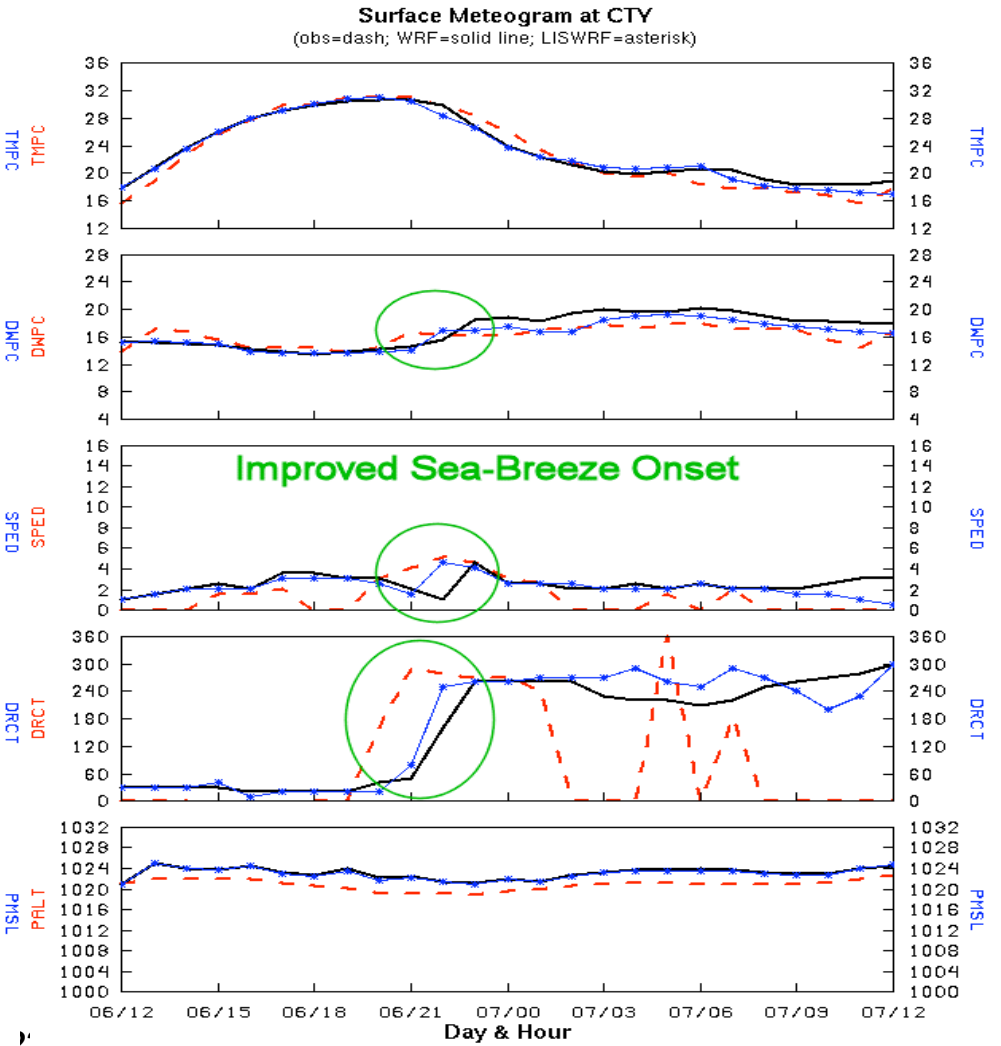
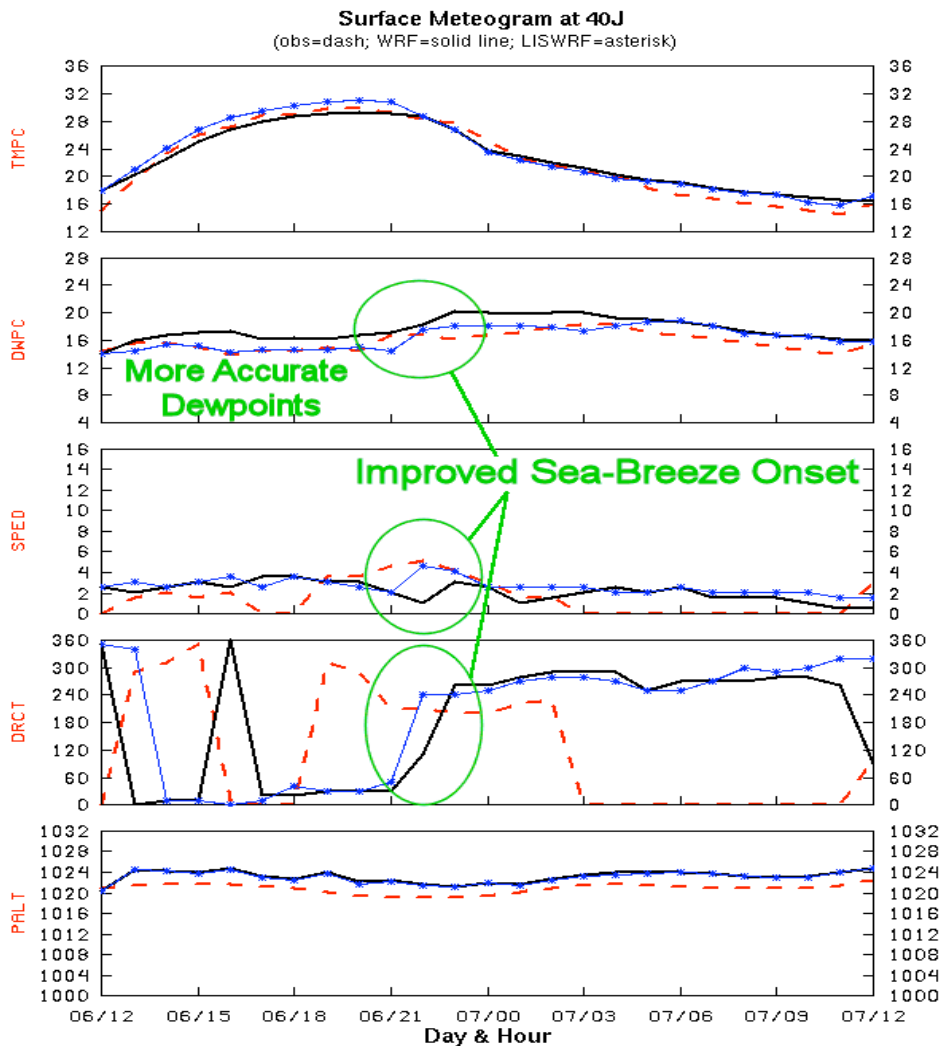
Case, Jonathan L., William L. Crosson, Sujay V. Kumar, William M. Lapenta, Christa D. Peters-Lidard, 2008. Impacts of High-Resolution Land Surface Initialization on Regional Sensible Weather Forecasts from the WRF Model. In press, Journal of Hydrometeorology.



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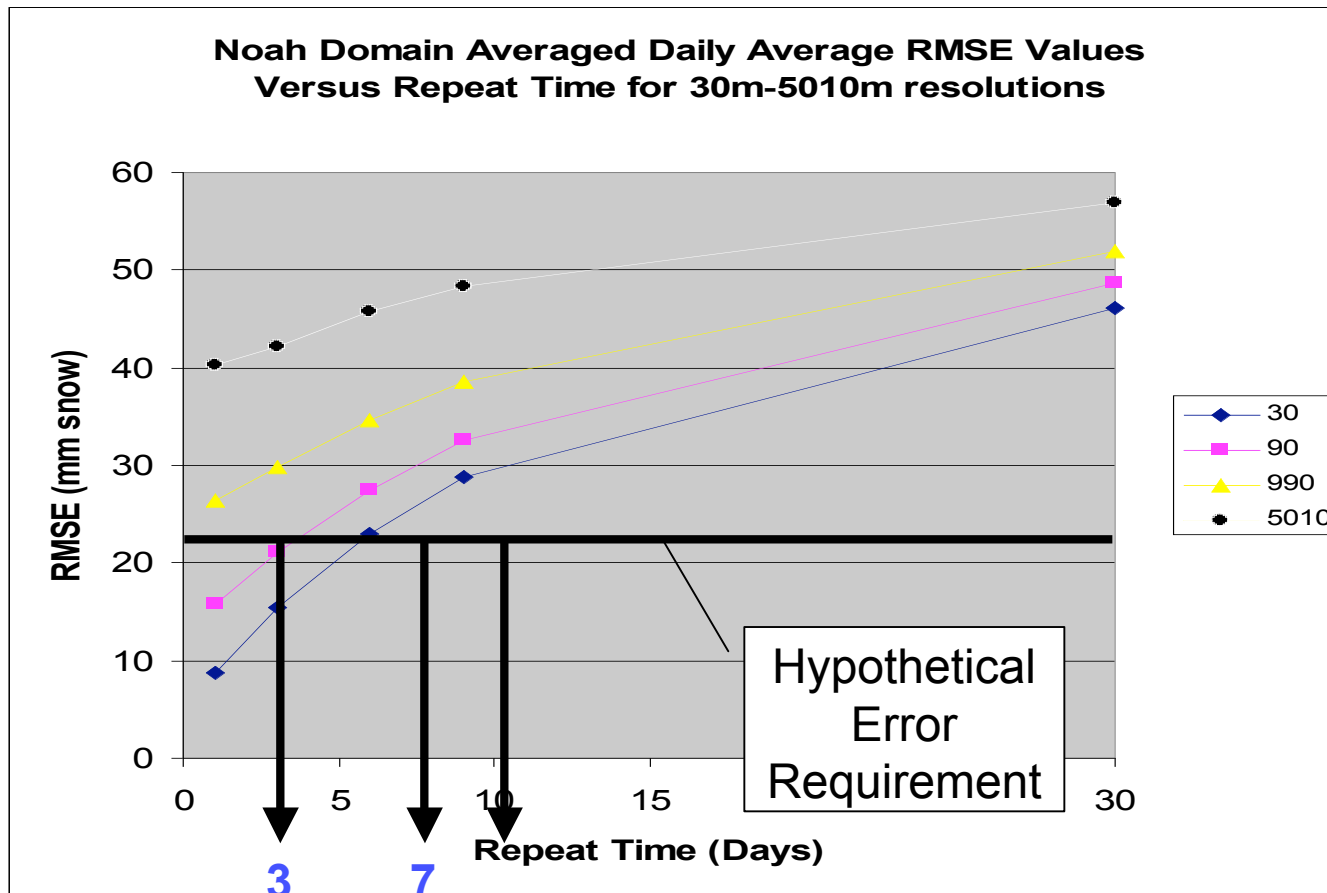


LIS-WRF Coupled Example 2: Sea Breeze Evolution Difference (Meteogram plots at 40J and CTY)



Use OSSE to Quantify Incremental Improvements to User DST

Cold Lands Process Pathfinder – Observation System Simulation Experiment



Goal: What time/space resolution Snow Water Equivalent (SWE) observations are needed?

Possible Application: End User Decision Support Tool Such as NOAA RFS CHPS DST to Quantify Benefits from Improvements to New Land Hydrology Sensors



Source: B. Cosgrove/NOAA and
P. Houser/GMU (Formerly NASA/HSB)

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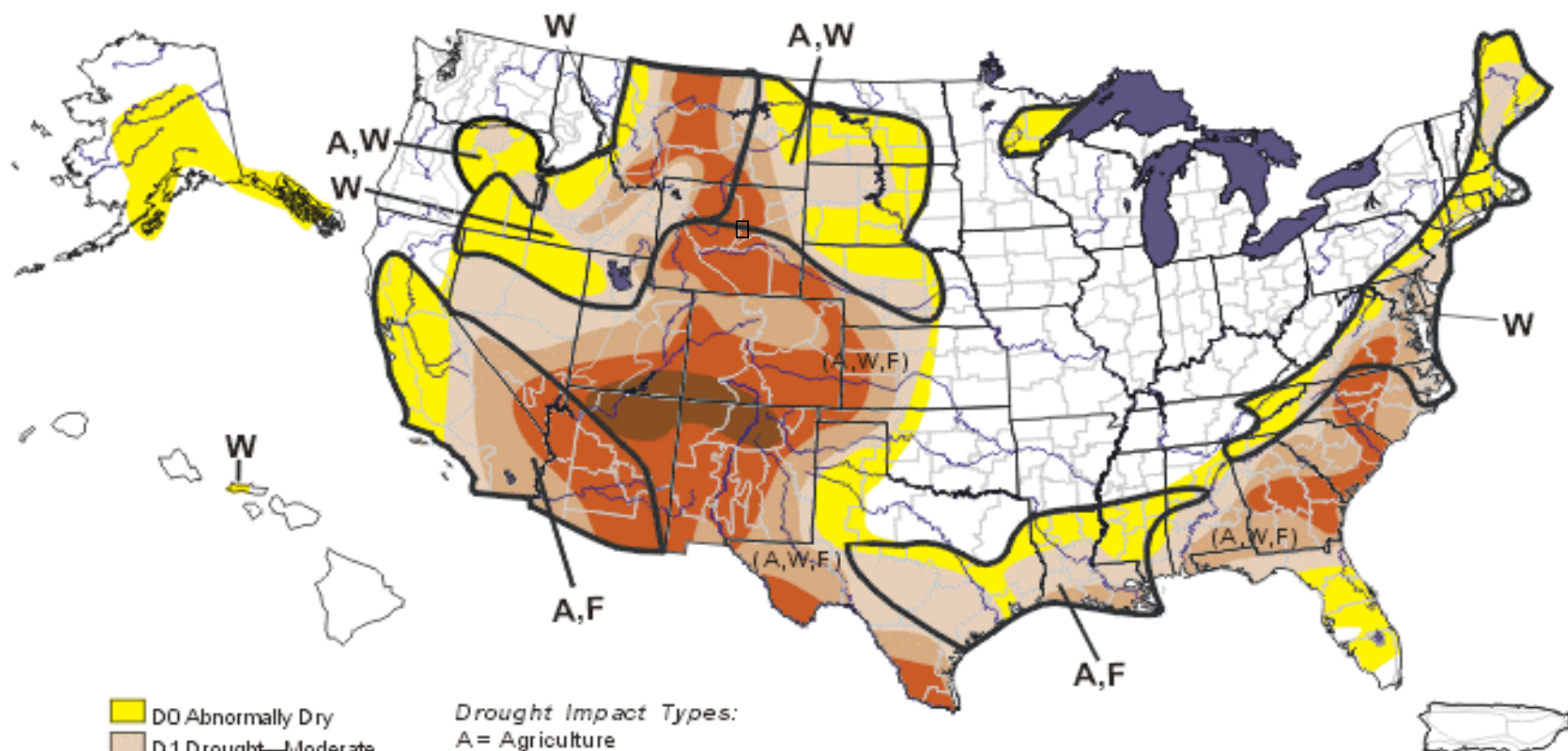


NASA Products for Selected Applications

U.S. Drought Monitor

June 11, 2002

Valid 8 a.m. EDT



- D0 Abnormally Dry
- D1 Drought—Moderate
- D2 Drought—Severe
- D3 Drought—Extreme
- D4 Drought—Exceptional

Drought Impact Types:

- A = Agriculture
- W = Water (Hydrological)
- F = Fire danger (Wildfires)
- Delineates dominant impacts
- (No type = All 3 impacts)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

<http://drought.unl.edu/dm>

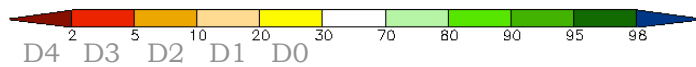
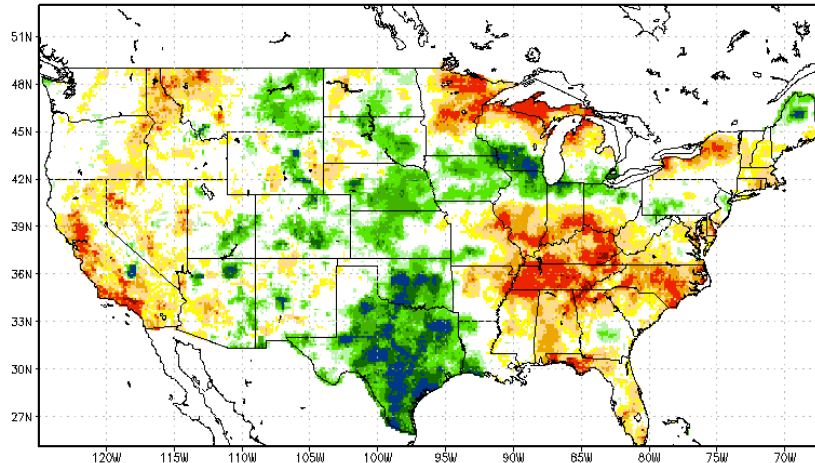


Released Thursday, June 13, 2002

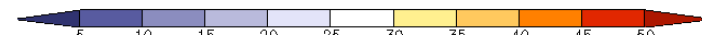
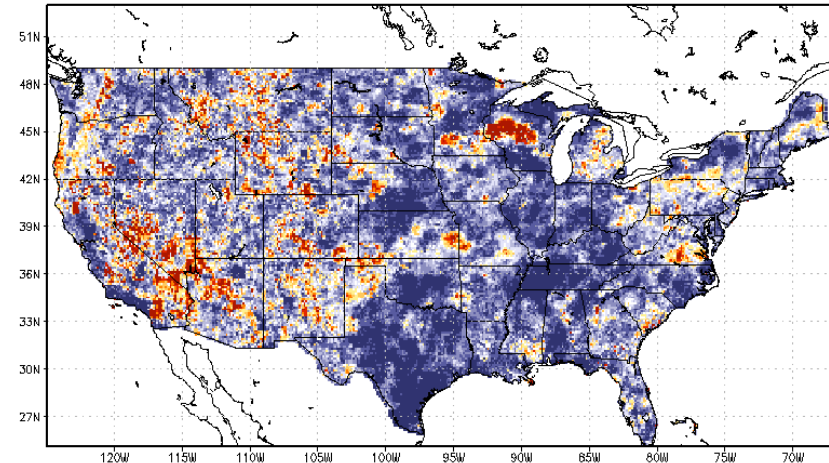
Author: Douglas Le Comte, NOAA A/CPC

Drought Monitoring Comparison

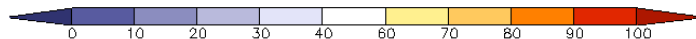
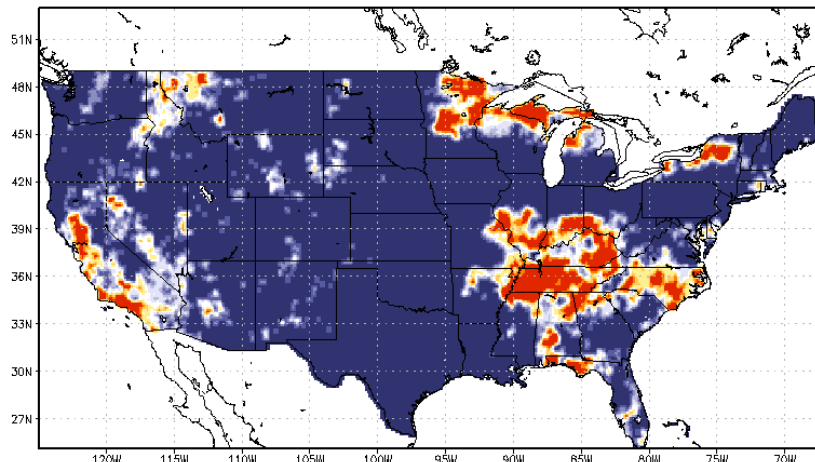
Ens. Mean – Total Column Soil Moisture Percentile
Valid: 20070901



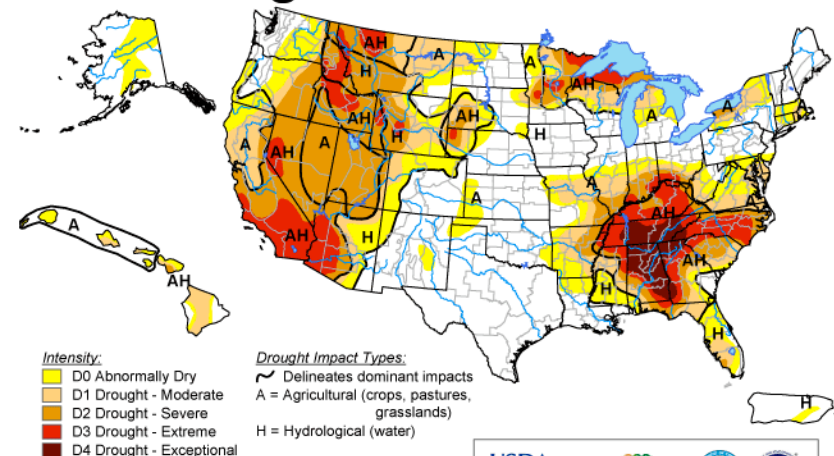
Ens. Spread – Total Column Soil Moisture Percentile
Valid: 20070901



Probability of Severe Drought (D2)
Valid: 20070901



U.S. Drought Monitor September 4, 2007
Valid 8 a.m. EDT



The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

<http://drought.unl.edu/dm>



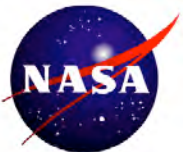
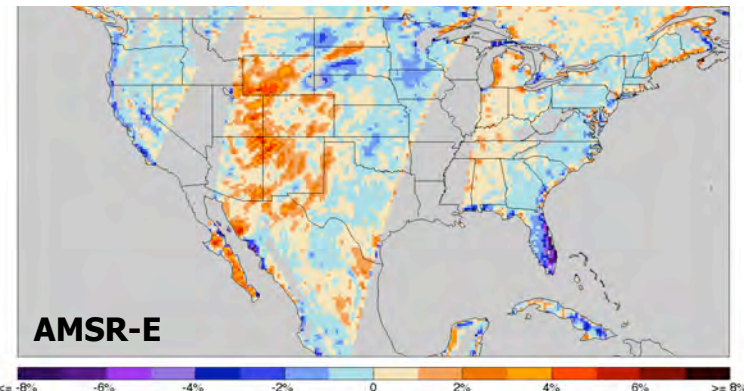
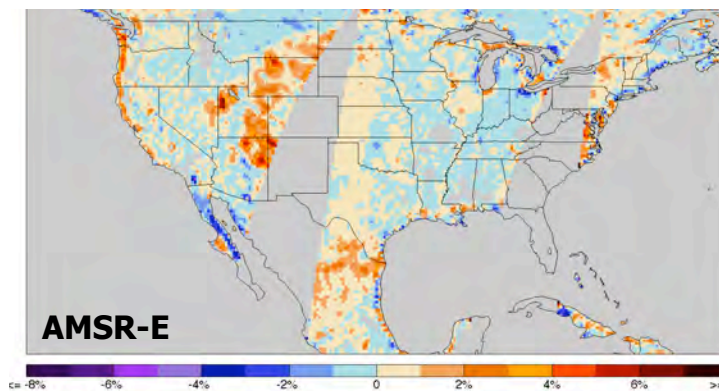
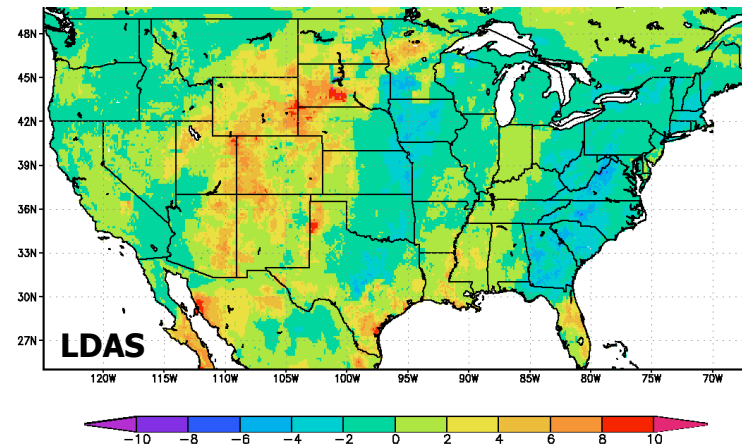
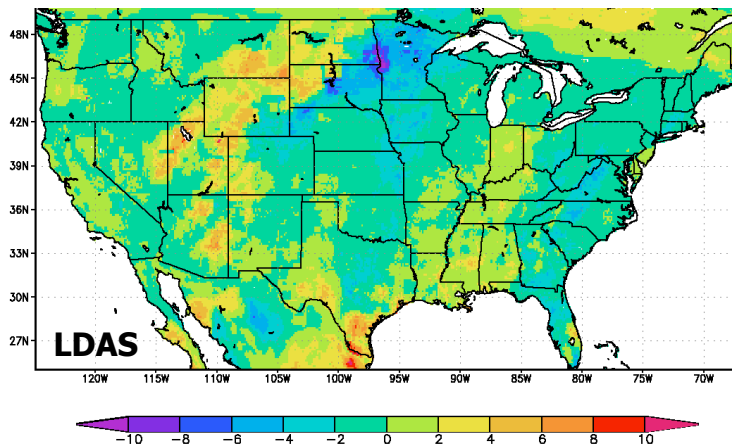
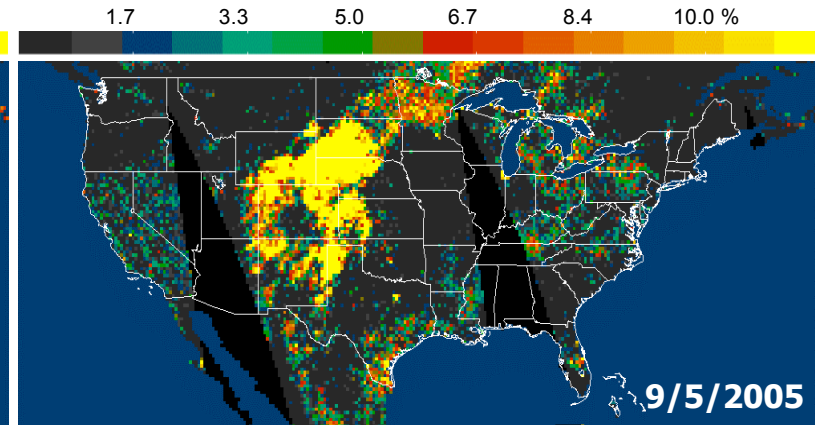
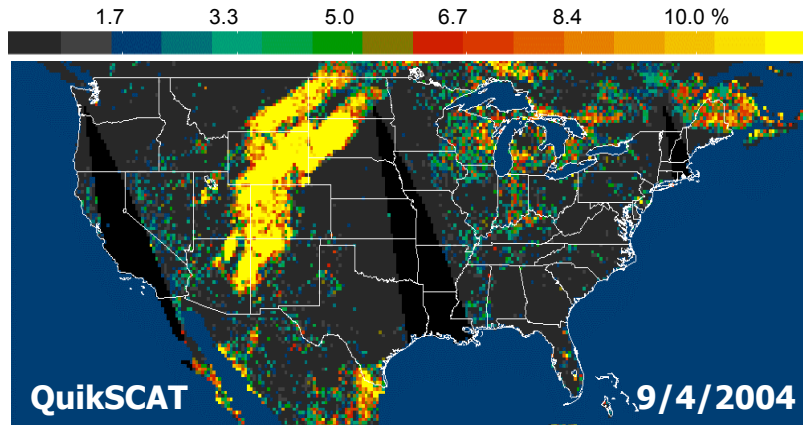
Released Thursday, September 6, 2007
Author: Thomas Heddinghaus, CPC/NOAA



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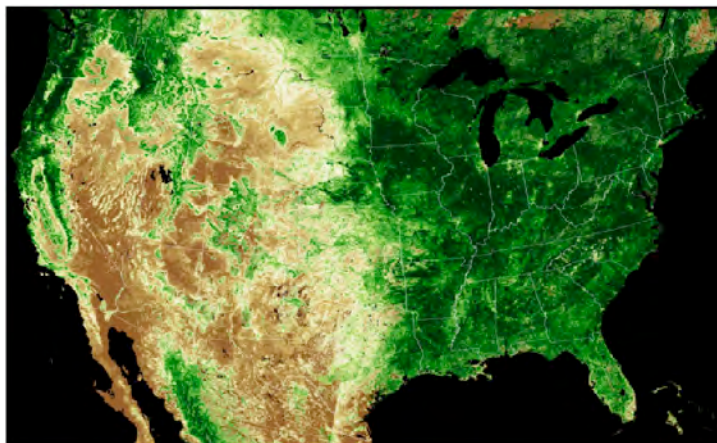


QSCAT, LDAS, and AMSR-E Products



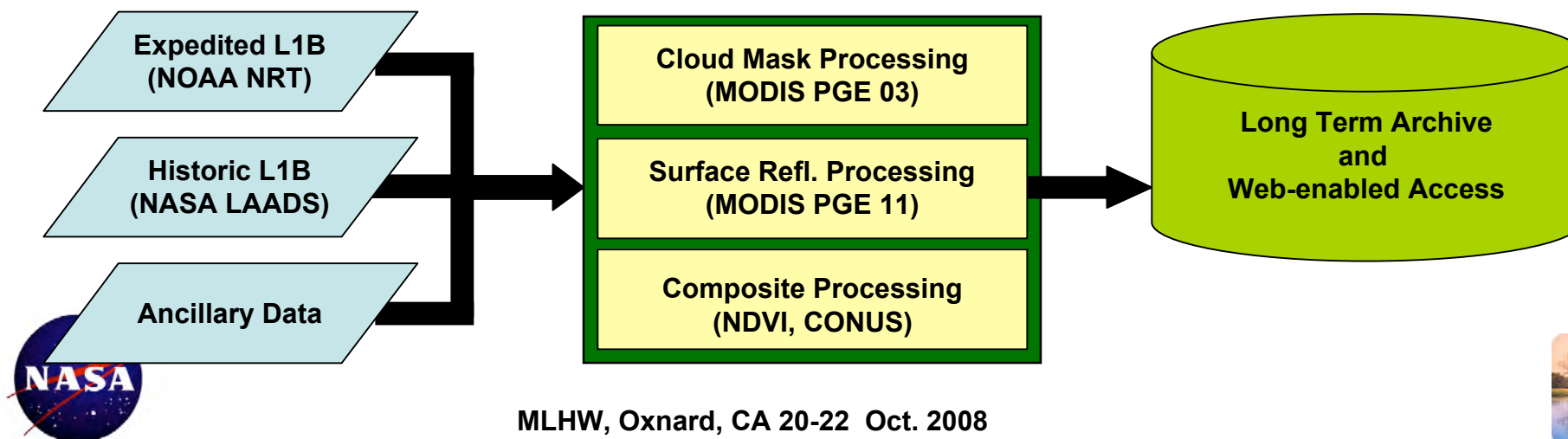
MODIS System Characteristics for Inputs to US Drought Monitor – PI J. Verdin (USGS)

Product Characteristics



	Expedited	Historic
Instruments	Aqua and Terra MODIS	
Extent	Continental U.S. (CONUS)	
Spatial Resolutions	250, 500, and 1000 meters	
Product Latency	~ 1 day after last input	< 30 days after last input
Archive Persistence	90 days	Indefinitely
Composite Period	7-day, Rolling	7-day, Interval
Layers	NDVI, Surface Refl. Bands, Quality, Acq. Date	
Projection/Format	Lambert Equal Area Azimuthal / GeoTIFF	

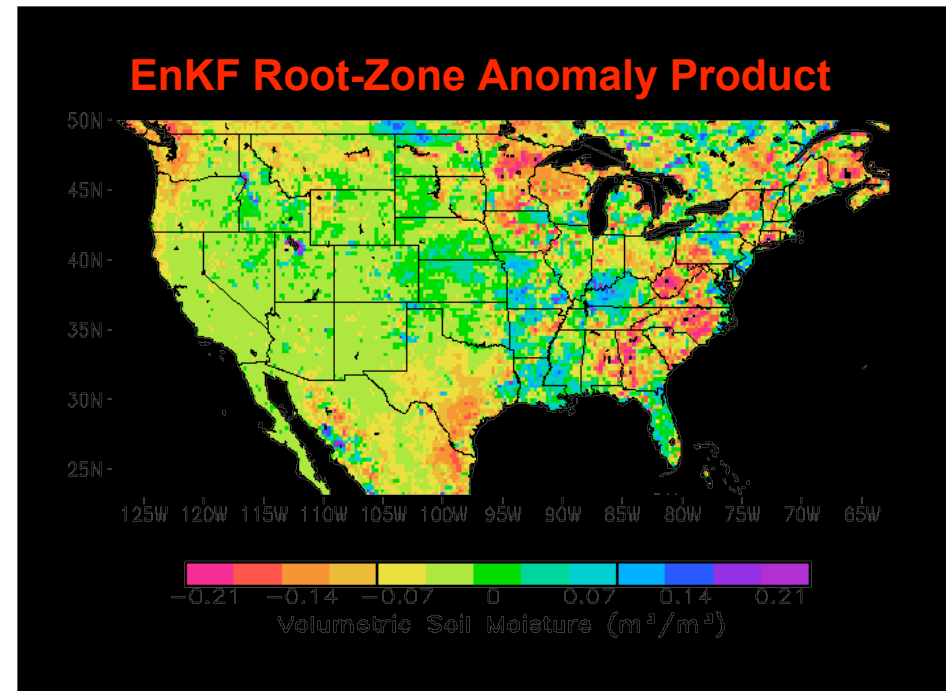
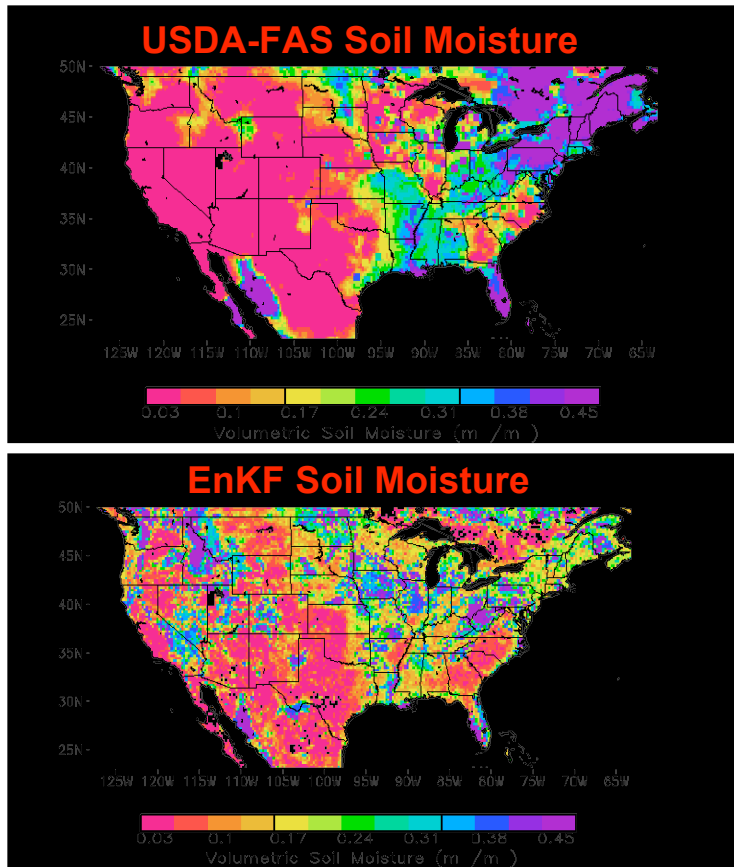
Processing Flow



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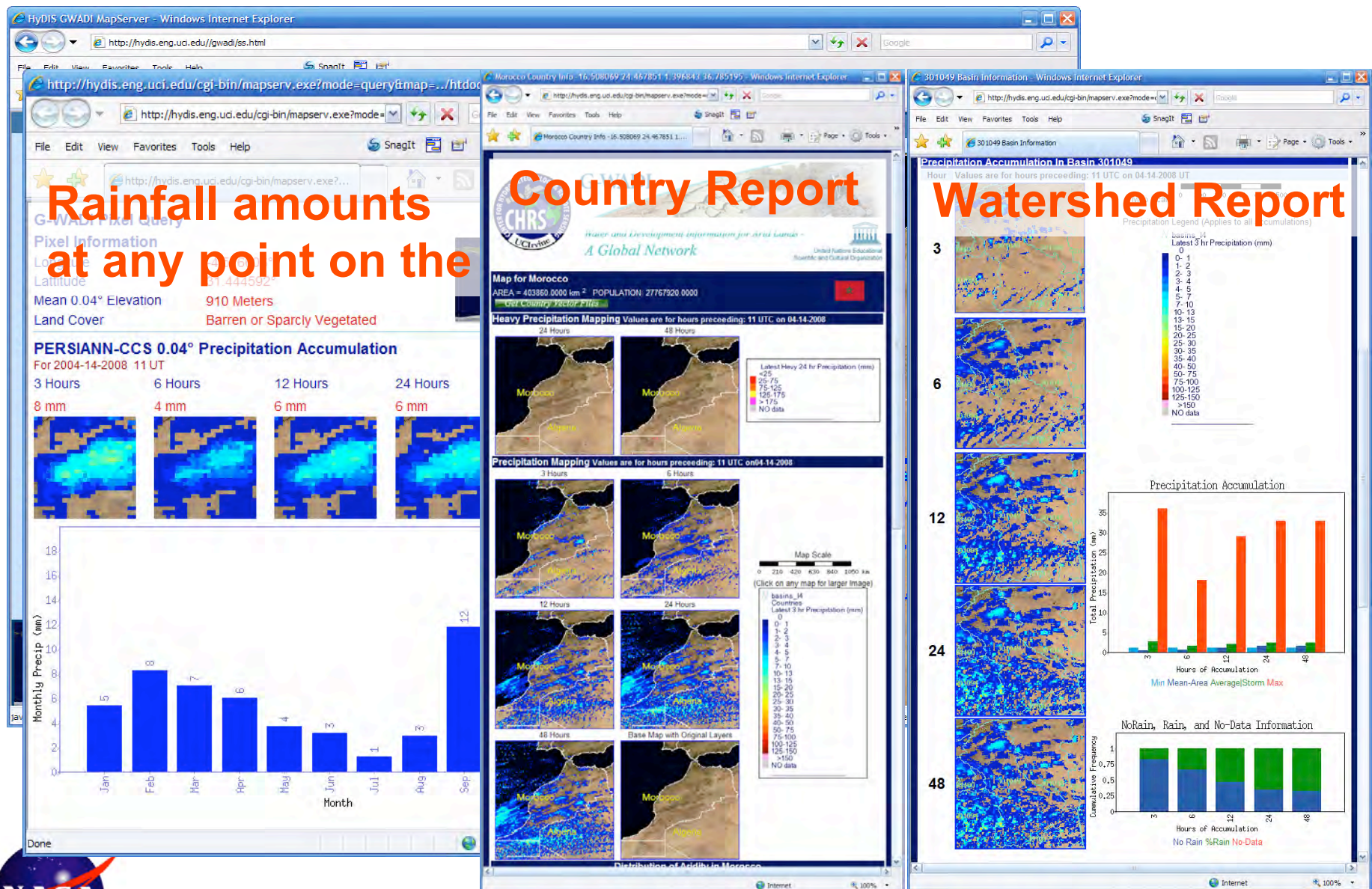
Integration of AMSR-E Soil Moisture into the USDA-FAS Global Crop Production Decision Support System



- **Contribution:** provide global soil moisture observations at higher accuracy, finer spatial resolution, and over broader geographic domains than existing USDA-FAS product
- **Benefits:** more accurate crop monitoring, greater agricultural economic security, improved food shortage warnings, increased agricultural efficiency, policy and resource management decision support
- **Status:** Operationally delivered to the PECAD DSS in near real-time

Bolten & Crow

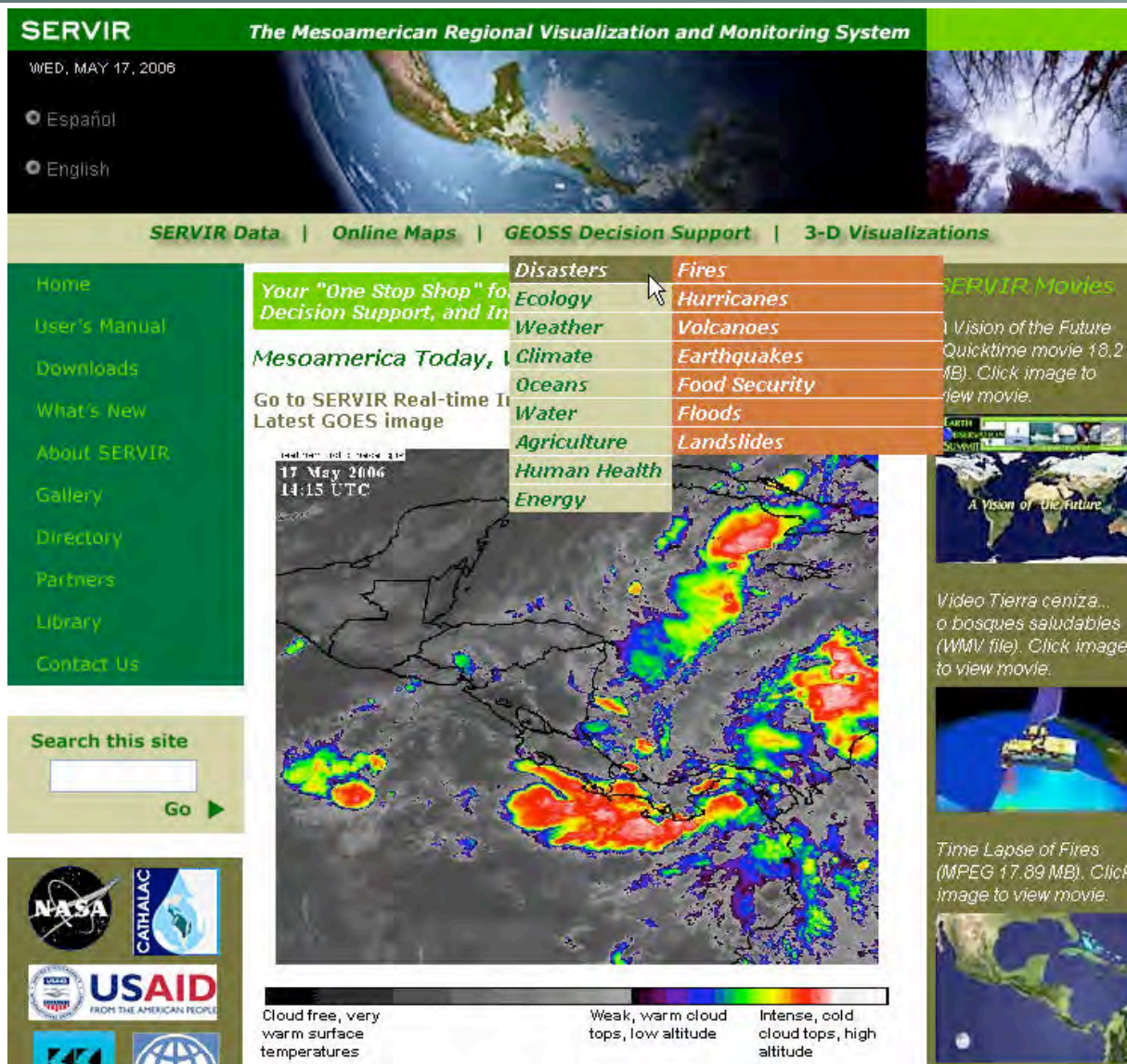
Satellite Rainfall Estimation: Research at UC Irvine



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Regional Visualization & Monitoring System ('SERVIR')



Web Site

<http://servir.msfc.nasa.gov/>

Four Main Sections

- 1) SERVIR Data
- 2) Online Maps
- 3) GEOSS Decision Support
- 4) 3-D Visualizations

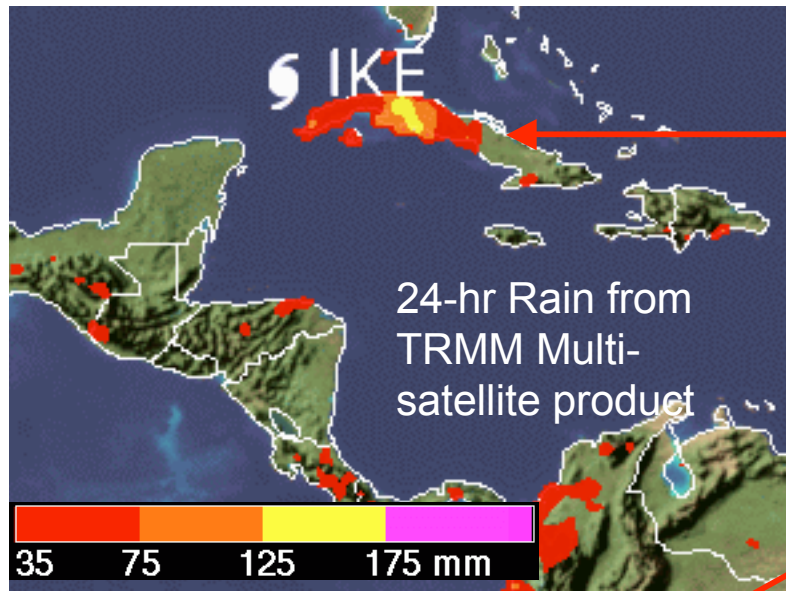
Highlights

- Real-time views of weather around Mesoamerica.
- Tools to monitor wildfires, floods, volcanoes, harmful algal blooms and ecological changes

SERVIR

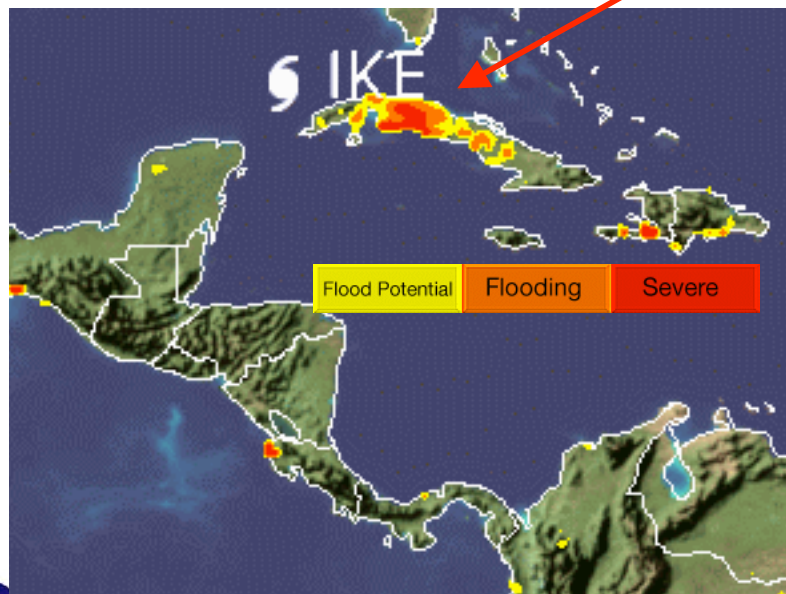
- NASA Partnering with USAID and others
- Recently Extended to E. Africa
- Potential for Additional Extrapolations

NASA GPCP



10 SEP 2008 0600 UTC

Hurricane Ike in Cuba--Heavy, but not extreme rain, flooding (calculated from hydrological model) and landslide potential (from real-time landslide algorithm) indicated along south side of mountains



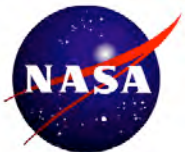
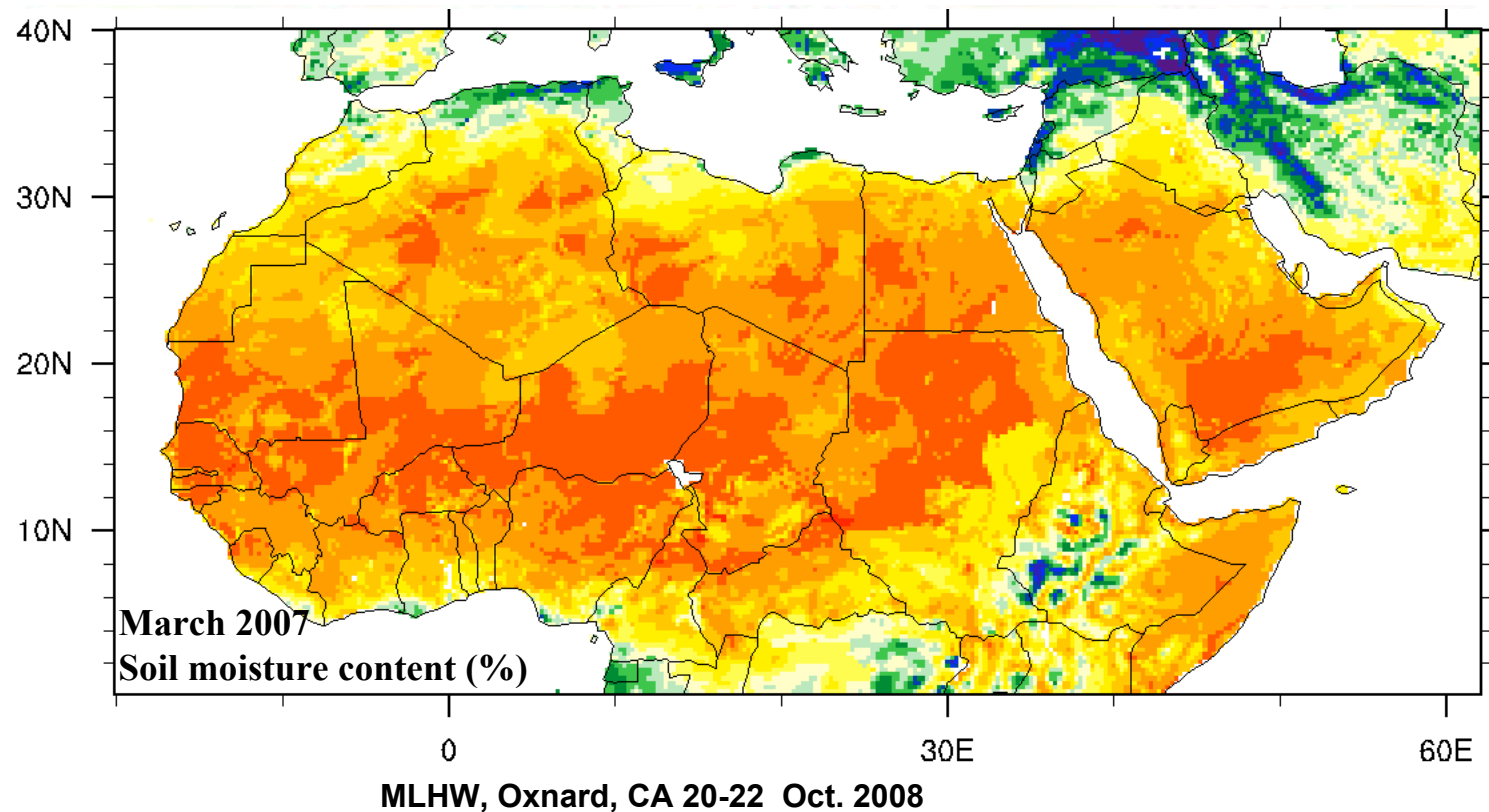
http://trmm.gsfc.nasa.gov/publications_dir/potential_flood_hydro.html

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Mid-East and North African Regional Water Balance

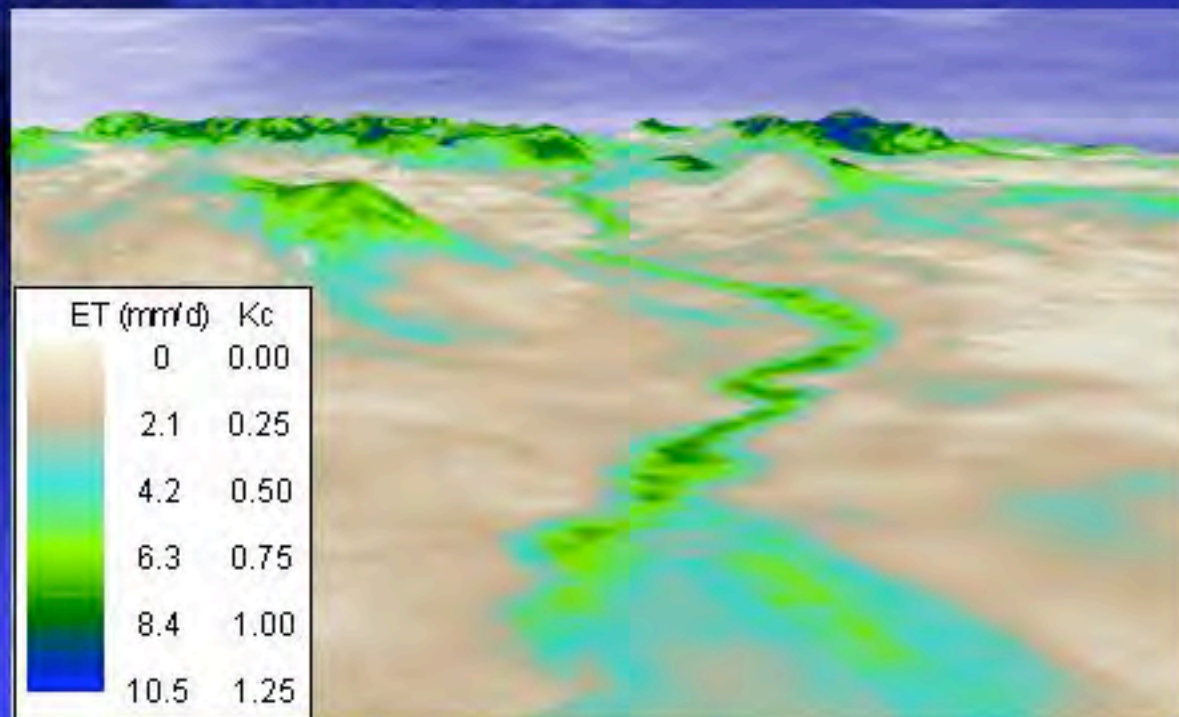
- The ***Arab Land Data Assimilation System*** will be optimized for member nations of the Arab Water Council. Funded by USAID Office of Middle East Programs in Support of Arab Water Council



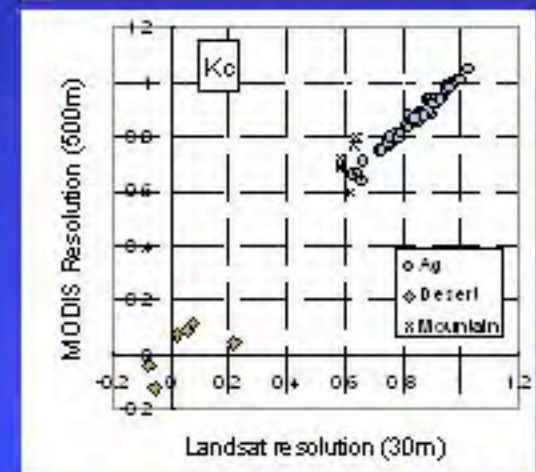
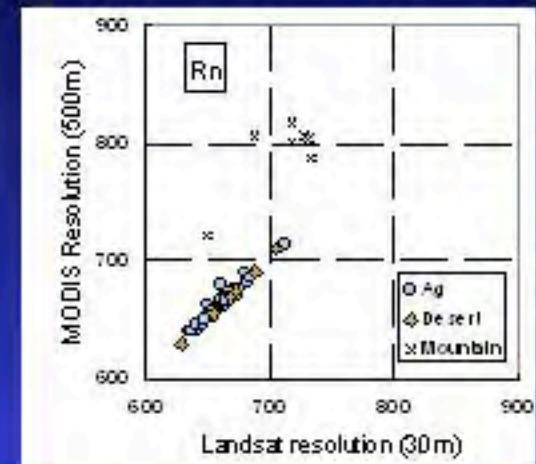
Translation of METRIC from Landsat to MODIS

(R. Allen, University of Idaho)

Applications with MODIS were tested using the original Landsat basis in Idaho and New Mexico



MODIS derived 3-D Evapotranspiration map
(MRG, NM, 8/26/2002)

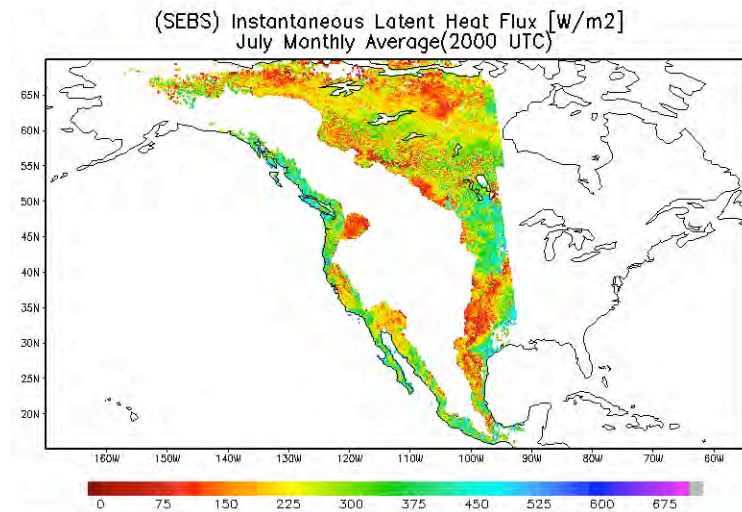
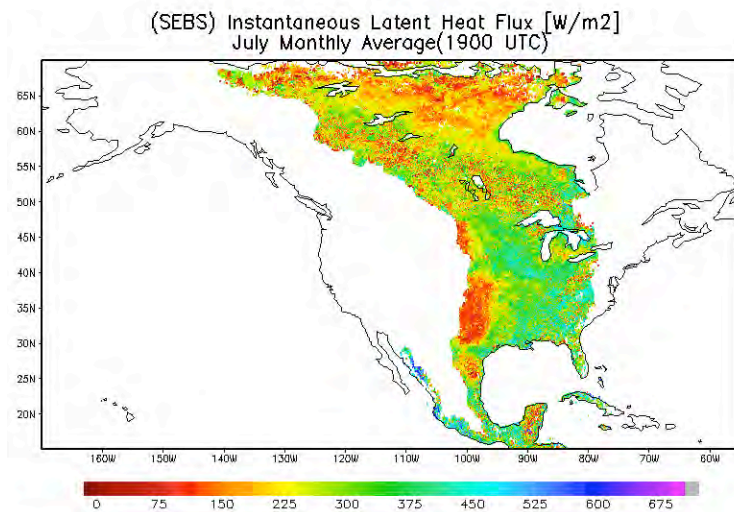
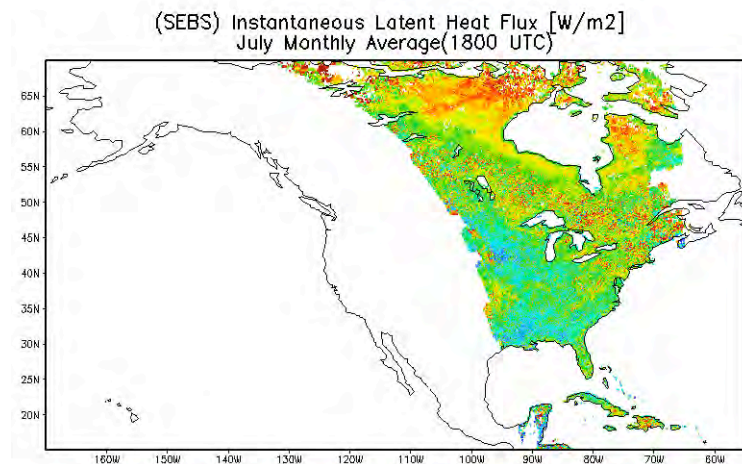
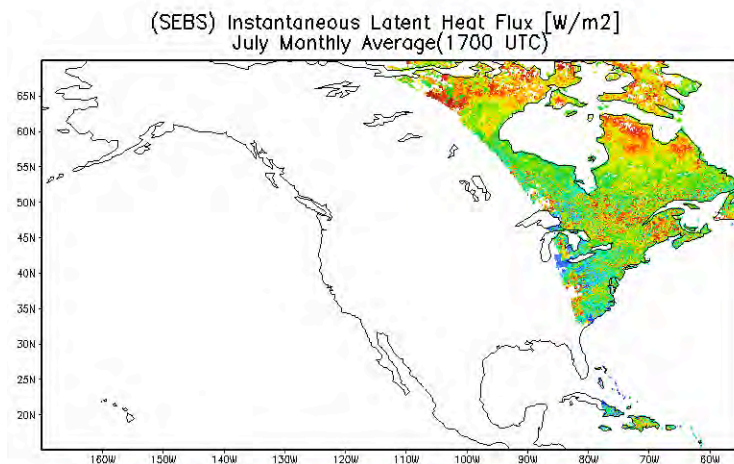


Comparison of Net Radiation and K_c estimation for MODIS and Landsat resolution.

Continental Scale Instantaneous ET

Monthly Average – July 2003

Using MODIS, CERES, AIRS and the SEBS surface energy budget algorithm



©ADS: COLA/IGES

©ADS: COLA/IGES

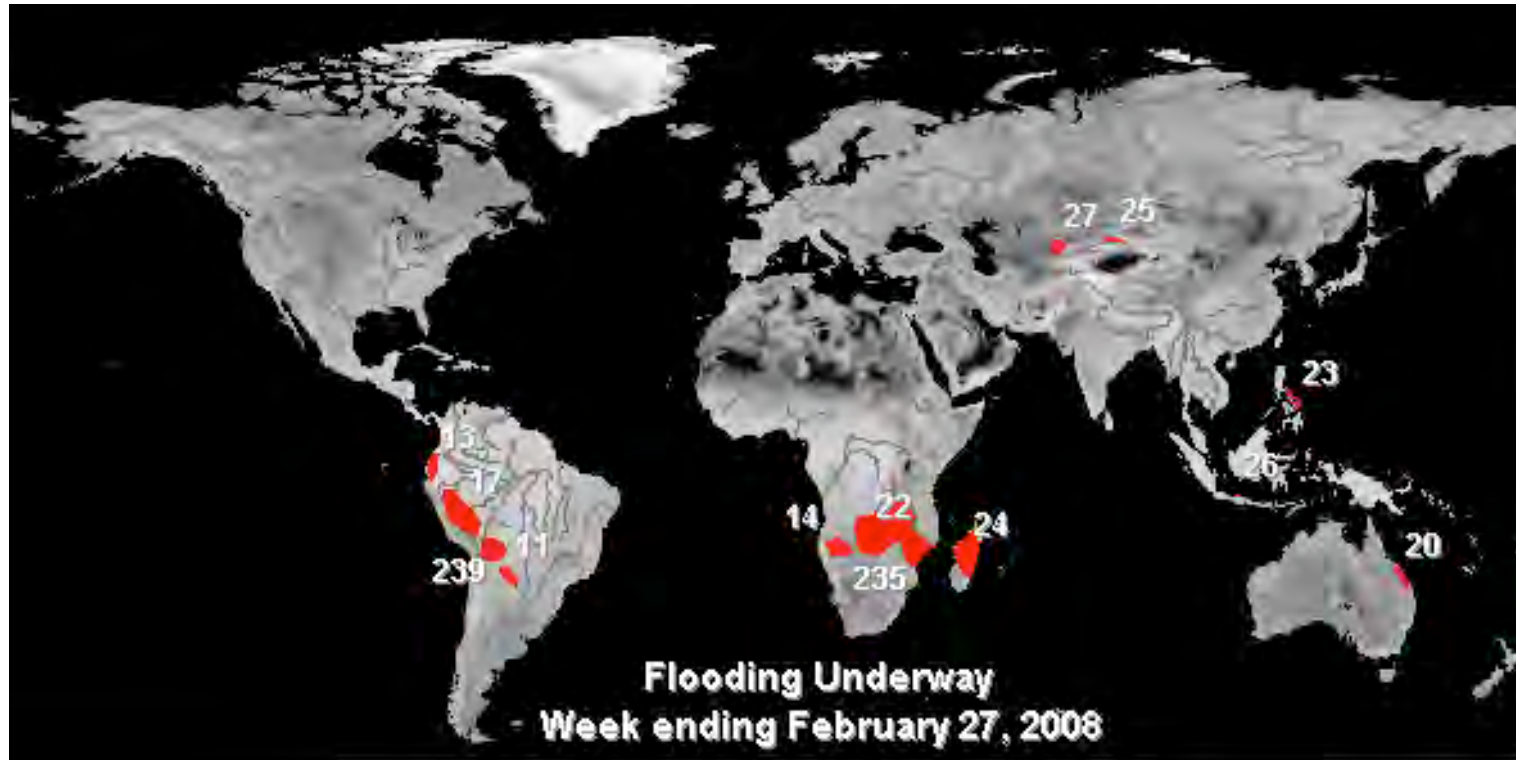


Streamflow Monitoring & the Dartmouth Flood Observatory

Robert Brakenridge

Dartmouth Flood Observatory

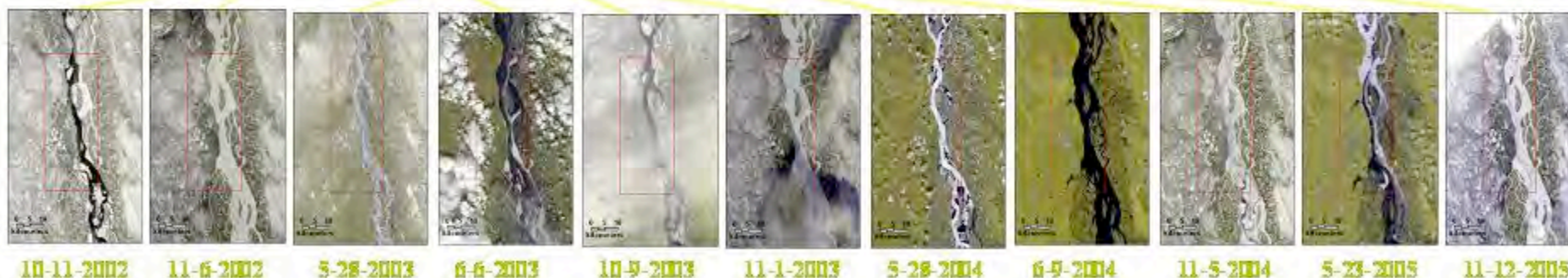
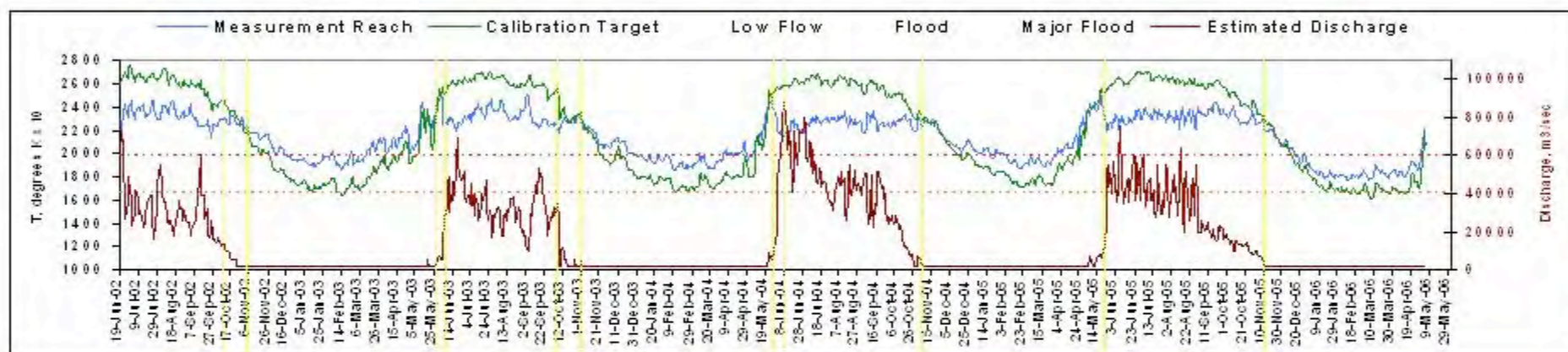
<http://www.dartmouth.edu/~floods/>



MLHW, Oxnard, CA 20-22 Oct. 2008



AMSR Stream Flow Measurement and River Ice Monitoring



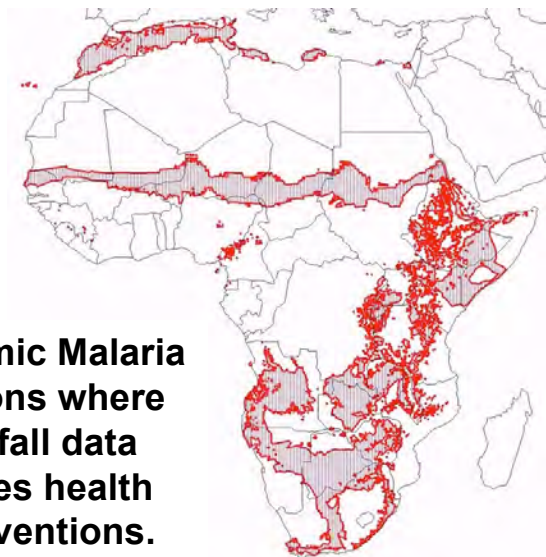
NASA funded project to Enhance the Malaria and Famine Early Warning System with NASA data

Using NASA data to assist FEWS NET to anticipate and warn of humanitarian crises.

- Projecting Rainfall and NDVI data 1-4 months in future for improved decision support.
- Integrated climate data for WHO HealthMapper for early identification of malaria epidemics.

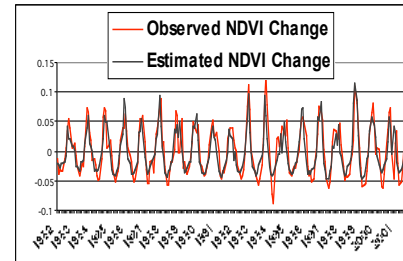
NASA Data to be Incorporated:

AURA MLS Relative Humidity
TRMM Precipitation
MODIS NDVI
GIMMS AVHRR NDVI

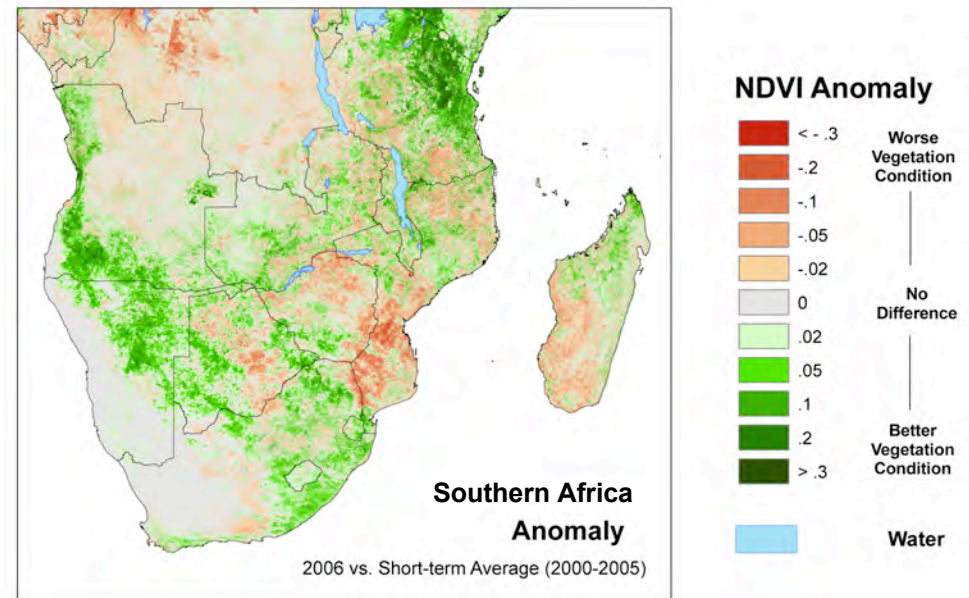


Epidemic Malaria Regions where rainfall data guides health interventions.

Funded from 2007-2009



Projecting MODIS NDVI data 4 months ahead will give advance warning to food and fodder production shortfalls.



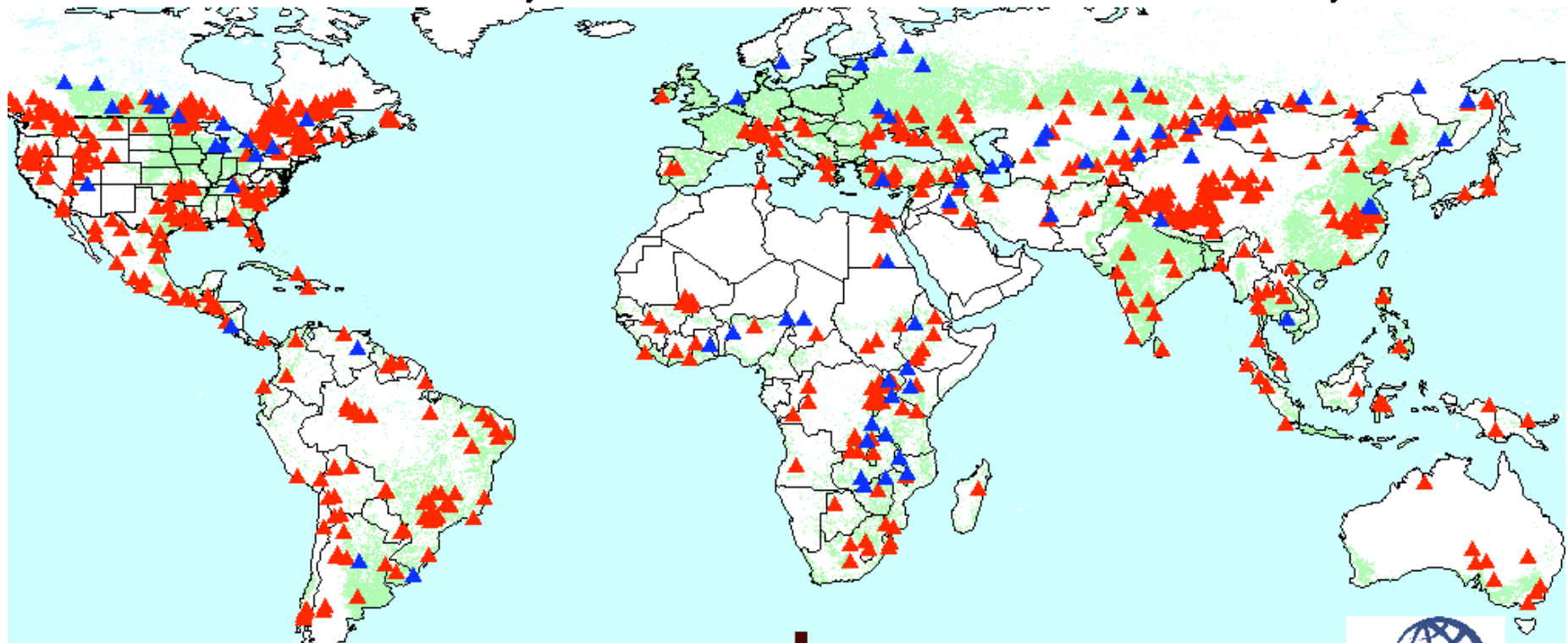
Funk and Brown, RSE 2006 v 101 p 249-256

Benefits: Improved response and recovery from food crises and epidemics, reducing costs to US Government and saving lives.



Phase V: Future Lake and Reservoir Operations (post April 2008, funding: NASA and USDA/FAS/OGA)

Current Lakes Monitored by Jason-1 and Potential Lakes Monitored by ENVISAT

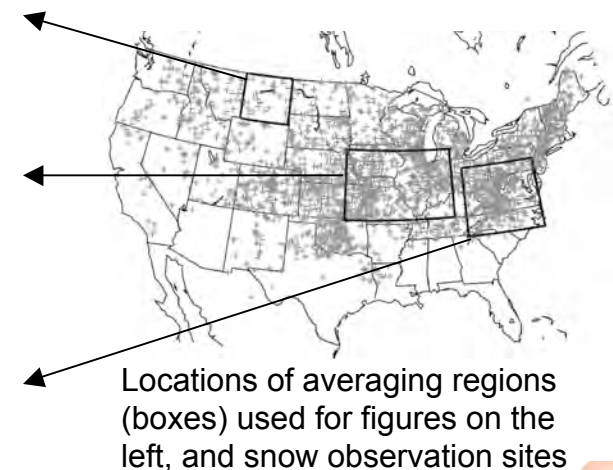
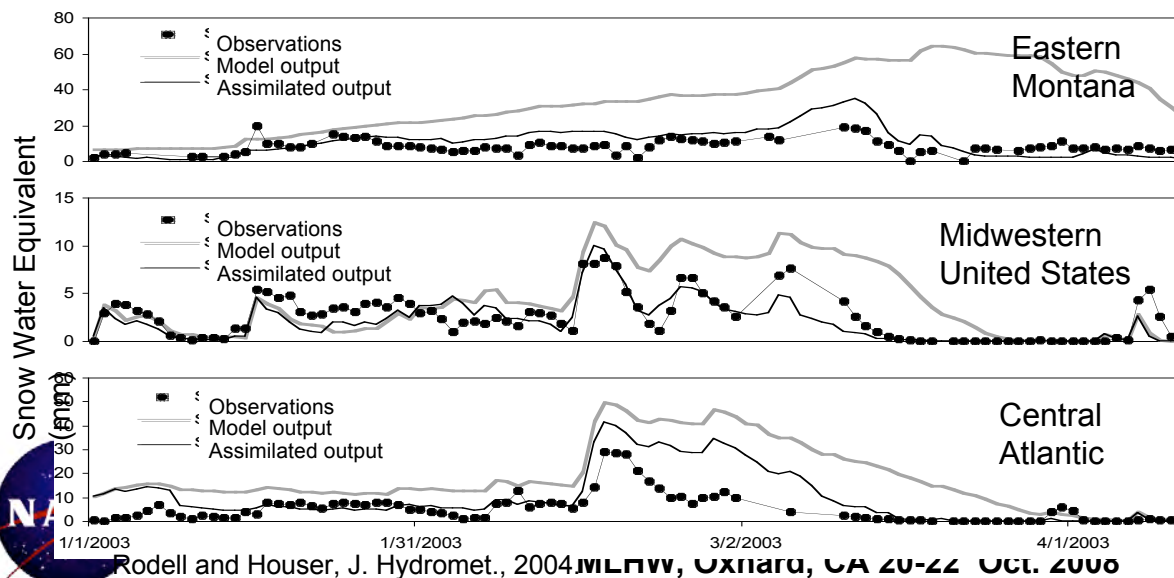
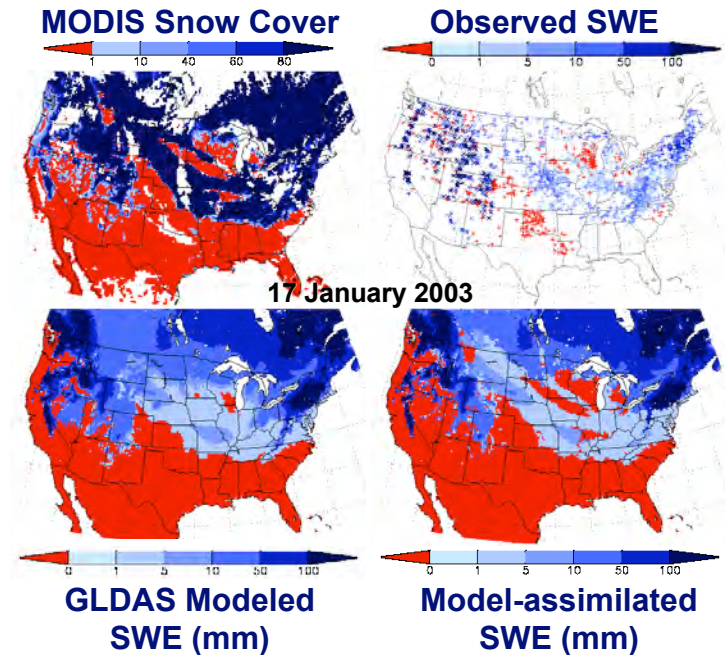


- ▲ Current Jason Lakes (73)
- ▲ Potential ENVISAT Lakes (611)
- Croplands



MODIS Snow Cover Improves Snow Water Equivalent

- Large gaps in ground based snow observations (right, upper right panel)
- MODIS observes snow cover globally, but not snow water equivalent (SWE) (right, upper left panel)
- The NASA Global Land Data Assimilation System (GLDAS) is capable of estimating snow water equivalent by assimilating MODIS snow cover in to models(right, lower left panel)
- Assimilation of MODIS snow into GLDAS models produces global SWE maps (right, lower right panel; and below)



Microwave Land Hydrology Applications

- **Applications** - Making MLHW data products and resources accessible to users and stakeholders beyond the traditional hydrologic science community by establishing broader and more effective use of space-based precipitation data products in decision-support of a wide variety of societal applications
 - Freshwater Utilization and Resource Management
 - Natural Hazard Monitoring/Prediction (Flood Warnings, Hurricane and Cyclone Observation, Winter Weather Events)
 - Operational Weather Forecasting
 - Climate Change Assessment
 - Agriculture
 - Transportation
 - Policy and Planning
 - Reservoir Planning
 - Hydro-Energy

